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# MANGROVE ECOSYSTEMS

## *A MANUAL FOR THE ASSESSMENT OF BIODIVERSITY*

A follow up of the
**National Agricultural Technology Project (NATP.), ICAR.**

*Mangrove Ecosystem Biodiversity :
Its Influence on the Natural Recruitment of
Selected Commercially Important Finfish and Shellfish
Species in Fisheries*

*Edited by :*
**Dr. George J. Parayannilam**

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Central Marine Fisheries Research Institute
*(Indian Council of Agricultural Research)*
P.B. No. 1603, Ernakulam North P.O; Cochin – 682 018, Kerala, India

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**MANGROVE ECOSYSTEMS**
**A Manual for the Assessment of Biodiversity**

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# FOREWORD

Coastal zones in the tropics are dynamic ecosystems undergoing constant adjustments consequent to natural processes and anthropogenic activities. Mangroves dominate the coastal areas in tropical countries and these wetland ecosystems are among the most productive and diverse habitats in the world. More than 80% of the marine catches directly or indirectly depend on coastal ecosystems including mangroves. Incidentally, coastal zone is also home for 65% of the global population; hence, the human interventions in these ecosystems are enormous. Demographic growth and migration to coastal areas and poor ecosystem management have contributed to the depletion and destruction of mangroves. In this context, the National Agricultural Technology Project (NATP) of ICAR made an attempt to conduct research and assessment of National natural wealth such as Coastal Agro-ecosystems under Production System Rresearch (PSR Mode) during 2001-2003. Accordingly a project funded by the World Bank for an extensive investigation on the "state of art" of selected mangroves of the country was sanctioned. The objectives of the project included inventorization of Biodiversity of major Indian mangroves and their influence on the marine capture fisheries resources of the country. In addition to the above, this programmme also attempted to create awareness and sensitize the local community in the rationale to prevent mangrove destruction and initiate concerted action for restoration.

No conservation programme is effective or meaningful without the participation of all stakeholders. Therefore, it was felt that a common minimum program must be formulated to achieve the objectives very rationally and to focus attention on the natural and social issues of mangrove ecosystem management. This Manual for the Assessment of Biodiversity is a follow up to the NATP, ICAR National project entitled "**Mangrove Ecosystem and its influence on the natural recruitment of selected commercially important fin fish and shell fish species in fisheries**." The need for such a manual on research methodology for assessment of biodiversity of a fragile, inhospitable, non-predictable but highly productive ecosystem which is considered as a national wealth has been long felt and this output is a fulfillment of the information gap. While, I congratulate the project personnel for bringing out this publication, I am hopeful that this will serve as a sourcebook for information for future research on biodiversity of mangroves of India and help in framing conservation and management strategies and policies through participatory approach.

**Prof. (Dr.) Mohan Joseph Modayil**
Director

## PREFACE

Research and reclamation/restoration leading to rational management of mangroves have been the objectives of the World Bank funded National Agricultural Technology Project (NATP) entitled "**Mangrove Ecosystem Biodiversity and its influence on the natural recruitment of selected commercially important fin fish and shell fish species in fisheries**" under Production System Research (PSR) of Indian Council of Agricultural Research (ICAR), New Delhi. This publication is a followup of the project and although the basic idea in the preparation of the manual has been to produce a simple outline of techniques and listing identification keys of organisms already established, it has many other utilities. This is meant mainly for the newcomers in the field and isolated researchers who have no access to the large libraries. It is more or less a compilation of the information gathered by earlier research workers and the project personnel on the mangrove biota. The best general advice is to conduct a preliminary survey to understand topography, size, range, type of biota, etc. of proposed mangrove that has to be investigated in detail later. While it is basically intended as an aid to those approach the mangroves first time, it is anticiapted that some chapters will be of greater use to seasoned researchers. The contents comprise the identification characters of common mangrove Macrophytic vegetation, Microalgae, Zooplankton, Benthos, Finfish, Shellfish, Reptiles, Mammals, Avian fauna & some methods for analysis of various aqua-edaphic parameters. The approaches to the studies on biodiversity, although satisfactory today, may need revision tomorrow. For this reason, it has not been possible to create a uniform entity, the primary task of the editor has been to balance, adjust and redistribute some of the individual contributions. A few of the sections originally planned have proved to be impractical at this stage and publication has proceeded in the hope that these points may be included in a later edition. The editor and contributors are responsible for the choice and presentation of the material in this manual and express regrets for any errors or omissions of attribution that may have been made.

A host of benefactors rendered their valuable guidance and help in formulating, implementing the project and preparation of this manual. In this context, the Principal Investigator /Editor records his utmost gratitude to Dr. S. L. Mehta, the then National Director, NATP, Dr. S. Ayyappan, DDG (Fisheries), Dr. A. D. Diwan, ADG (Marine Fisheries) ICAR and Dr. S. Edison, Director, Agro-Ecosystem, (Coastal) NATP for their liberal help. The advice and guidance of Dr. E. G. Silas, former Director, CMFRI, Cochin and Vice Chancellor, Kerala Agricultural University and Member, Scientific Advisory Panel (SAP), NATP for the preparation and implementation of the project are gratefully acknowledged. I am thankful to Dr. M. Devaraj, former Director, CMFRI, Cochin and Member, Scientific Advisory Panel (SAP), NATP for the suggestions and recommendations to formulate and restructure the project. I am deeply indebted to Prof. Dr. Mohan Joseph Modayil, Director, CMFRI, Cochin for the wholehearted support, constructive criticism and advice for this endeavour. The valuable help and advice provided by Dr. M. Rajagopalan, Principal Scientist & Head, FEM Division of CMFRI throughout the period of the project is thankfully remembered. I am extremely obliged to Dr. K. K. Appukuttan, Principal Scientist, Head MFD & Chairman, NATP cell, CMFRI, Cochin for managerial directions during the period of the project and preparation of this manual. On this occasion, the editor's task is also to thank the contributors, the details of them have been incorporated in this manual. The Principal Investigator/Editor does this with great pleasure, for, all of them have really generously dedicated their time to the none-too-easy task. In addition, I am indebted to a host of persons at CMFRI, Cochin, Kerala, Vidyasagar University, Midnapore, West Bengal and CARI, Port Blair, Andaman and Nicobar Islands and a number of other colleagues whose help I sought as and when required that unhesitatingly extended in the stupendous task of preparation of this manual. Last but not the least, I thank 'The Almighty' in whose kindness and blessings the present work has attained its fulfillment.

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# CONTENTS

# Mangrove Vegetation

**P. K. Jayasurya, P. Kaladharan, M. S. Rajagopalan, S. Dam Roy and A. K. Sadhu**

## Introduction

Mangrove vegetation includes plants ranging from herbs, shrubs to tall trees. In favourable conditions the mangrove trees can form dense forests in intertidal habitats. However; only a few species form a massive canopy.

The main characteristic features of these special type of plants are the **tidal amplitude**, defined by the species, and their ability to tolerate high salinity and stress. The majority of the plant groups have adaptations like **prop and stilt roots** for fixing support and the **pneumatophores** otherwise called the **breathing roots** for exchanging gases and the **viviparous** germination. In addition to these, the plants have leathery, dark, ever green leaves with deeply embeded stomata and aquous tissues.

The ecosystem is rich in organic production through the decay of the various plant litter and also by the influx of nutrients from the sea and land, which provide **an ideal nursery ground for many acquatic organisms.** The plants with aerial roots and the pneumatophore belts **give shelter for the juveniles** of Fishes, Crustaceans and Shellfish. The main type of root system of these plants also trap the rich nutrient ladden soil and provide a favourable ground for the growth of many species besides preventing soil erosion.

The major species of mangrove flora and their associates, with identification keys and also the main characteristic features are given below:-

### FAMILY : RHIZOPHORACEAE

Leaves coriaceous; corolla convolute or inflexed in bud; stamens 8 or many; anthers one celled, ovary inferior.

**GENUS**

**1(a)** Moderate trees with extensive stilt roots or looping bow-roots;flowers tetramerous....................... **4. *Rhizophora* L.**

**1(b)** Small to moderate trees, without extensive aerial stilt like or bow like roots; flowers pentamerous or with more floral segments .................................................................. **(2)**

**2a (1)** Moderate tree without any aerial root like pneumatophores or stilt roots; stamen numerous ................ **3. *Kandelia* W & A**

**3b (1)** Small to moderate trees or shrubs; aerial roots knee like, rounded or knobby apex on the aerial roots; stamens twice as many as the calyx lobes, petals with marginal hairs ................................................................. **(3)**

**3a (2)** Moderate trees; leaves usually more than 12 cm long, apex usually acute; calyx 8-16 lobed; hypocotyle with persistant thin calyx teeth, scarcely ridged .......... ***1.Bruguiera* Lamk**

**3b (2)** Shrubs or small trees, leaves usually less than 10 cm; rounded apex; calyx 5-6 lobed; hypocotyle ridged, persistant calyx dried and less prominent .................... ***2. Ceriops* Arn.**

### 1. *Bruguiera* Lamk.

**SPECIES**

**1a**. Flowers usually larger, 3-4 cm long, reddish; petals upto 16 mm long ............................. **(2)**

**1b**. Flower usually small, 1-2 cm long or smaller, not reddish; petals 1.5 to 4 mm long …....................…..................... **(3)**

**2**. Leaves elliptic oblong; petal lobe tip acute with three filamentous appendages ......………… **2 *B. gymnorrhiza* Lamk.**

**3a (1)** Calyx lobes slender, short upto 3mm; spreading in fruits; petals 1.5 to 2.0 mm long ..…......... ***3. B. parviflora* W. & A.**

**3b (1)** Calyx lobes stout, long upto 5mm, refexed in fruits; petals 3-4 mm long...........……………

***B. cylindrica***

**1.1 *Bruguiera cylindrica* (Lamk)**

A true mangrove species. Tall tree, upto 25 m height, bark smooth, grey with few lenticels, leaves oblanceolate, rarely elliptical acute or bluntly pointed apex, 15 cm long and 5 cm broad. Flowers 0.8-1.2 cm long, greenish: calyx tube very small smooth, 8-10 lobes: petals 0.3-04 cm long. Fruits up to 1.5 cm long.

***Bruguiera cylindrica***
(Source - Dam Roy S., 2003)

**1.2 *Bruguiera gymnorrhiza* (L.)** (Fig. 1)

Maximum height, 15-20m; tall tree, much dense branched spreading, branches and stems marked with leaf and stipule scars. Short or shallow buttress like aerial roots, thickened trunks base, leaves elliptic oblong, acute apex, or bluntly pointed, coriaceous 7.5-15.0 cm long and 5.0 to 7.5 cm broad, dark green. Flowers solitary axillary, calyx deep orange red/yellow ribbed, campanulate large flowered 3-4 cm. Calyx tip acute, 11-13 numbers. Petals 1.2-1.6 cm long, tip acute with three appendages (Hypocotyl cigar shaped)

**Fig. 1. *Bruguiera gymnorrhiza***

**1.3 *Bruguiera parviflora* Wight & Arnold**

Medium tree upto 16 m height; branches not spreading, much smooth grey bark. Shallow butteresed from the trunk base, root-knees occasionally blunt end, pneumatophores present, leaves simple, 7.5-10.0cm long and 2.0-4.0 cm broad, oblong lanceolate or elliptic lanceolate, brightly shining above, dull beneath, glabrous. 2-5 flowered erect cymes, 2 cm long; calyx tube ridged. Petals 1.5 mm long, flower yellow-greeny fruit, obconical.

**2. *Ceriops* Arnold**

**2.1 *Ceriops tagal*** (Fig. 2)

Ever green small or moderate tall tree, canopy conical. Aerial roots form shallow buttressed and root knees or flange like plank roots in the base of the trunks. Leaves simple 8-10 cm long and 4-5 cm broad, obovate-oblong, apex rounded, glabrous. Flower small (5-7mm) in axillary cyme, sepals 5 lobed, petals 5, white, shorter than calyx. Fruits slightly conical 1.5 to 2.0 cm long, pointed apically. (Hypocotyl ridged)

**Fig. 2. *Ceriops tagal***

**3. *Kandelia* Wight and Arnold**

**3.1 *Kandelia candel* (L.)** (Fig. 3, Plate I)

Small to medium tree, upto 7 m height; bark smooth greenish or reddish brown; without any aerial roots, but occasionally aerial roots develop in some cases, leaves opposite, oblong-elliptic apex obtuse, 6.5-10 cm long and 2.5-4 cm broad, dark green and polished above. Flowers white 1.5-2.0 cm long in axillary cymes, 4-9 flowered, calyx lobes linear acute, petals bifid. Fruits 1.5-2.5 cm long. (Hypocotyl slender and pointed)

**Fig. 3.** ***Kandelia candel***

### 4. *Rhizophora* L.

**SPECIES**:

**1a** Leaves dark green, tips acute; inflorescence 2 flowered cymes; Petals glabrous; stamens 12; stigma almost sessile; fruits and seedling maturing well below twig . **4.1.** ***R. apiculata***

**1b** Leaves dark green, tips pointed, mucronate; inflorescence more than 2 flowered, cymes; petals hairy; stamens 8; stigma sessile; hypocotyle warted ... **4.2.** ***R. mucronata*** **Lamk.**

**4.1** ***Rhizophora apiculata***

Medium tree, upto 20 m height, coexist with other members of *Rhizophoraceae*; branches much spreading horizontally and erect with prominent fallen leaf scar marks, looping stilt roots upto 3-5 m height, occasionally bending like bow or pendulous/hanging roots, 5-10 cm diameter of these aerial stilt roots. Leaves dark green glabrous, oblong lanceolate, acute, petiolate. Flowers in pairs, white stigma almost sessile. Fruit 2.5-3.0 cm long, seedling radicle length upto 50 cm, radicle surface smooth, collar present.

**4.2.** ***Rhizophora mucronata*** **Lamk** (Fig. 4, Plate II)

Medium tree, upto 20 m height, coexist with *Ceriops spp*; and *Bruguiera spp*; branches spreading horizontally and erect marked with fallen leaves-scars. Stilt roots looping from the lower trunks and horizontal branches, form very gregarious dense growth of corky, fleshy, cylindrical 5-6 m long, 5-6 cm diameter Sometimes hanging from the trunk or bow roots, leaves dark glossy green, thick and cuticularised, 15 cm long & 8 cm broad, apex pointed, mucronatae. Flowers white, large in few flowered axillary cymes, 2-3 chotomously branched; stigma sessile. Fruit coriaceous 2.5-3.5 cm long. Cotyledonary collar absent in the radicle with warted surface and more pointed.

**Fig. 4.** *Rhizophora mucronata* in the middle flanked by *Rhizophora apiculata*

## FAMILY: AVICENNIACEAE

### *Avicennia* L.

**SPECIES:**

**1.** Leaves never glacious, whitish underneath, coriaceous, elliptic oblong or ovate-oblong, obtuse, glabrous, smooth & shining above ................................. ***A.officinalis*** **L.**

**1.** ***Avicennia officinalis*** **L.** (Fig. 5)

True mangrove species, medium tree upto 20m height with smooth bark. Branches both spreading and erect. Pencil like pneumatophores; occasionally stilt roots present; all these aerial roots with thick corky aerenchyma cells and numerous lenticels present on the cortex, leaves coriaceous, elliptic, oblong or obovate oblong, very obtuse or rounded apically, glabrous, smooth and shinning above, never glaceous whitish beneath, 10-14 cm long and 4-6 cm broad. Flowers zygomorphic; sessile in compact heads, 6-8 mm in diameter corolla orange/ yellow, glabrous within tetramerous, capsule contain 4 seeds - seeds flattened with in testa.

**Fig. 5.** ***Avicennia officinalis***

## FAMILY: SONNERATIACEAE

**SPECIES:**

Plants moderate to tall trees, (6-8 m) in the inner estuary, twigs, diffused branched, slender occasionally slightly pendulous, leaves glabrous opposite, elliptic oblong or oval obovate with short petiole, mid vein often red at base, in conspicuous without prominent vines, petals slender reddish alternate with calyx, best seen in flower bud ... ***Sonneratia caseolaris*** **(L.) Engler.**

**Fig. 6.** ***S.caseolaris***

## FAMILY: PLUMBAGINACEAE

Cosmopolitan in distribution consisting of herbs or low-shrubs, common in mangrove habitat. Family characters are abundant scleroids, secondary thickening, viviparous seed germination.

**Genus :** ***Aegialitis***

Salt water loving plants, swollen trunk base, fluted axis, conspicuous annual leaf scars. Flower pentamerous, bisexual, regular with bract and bracteoles white.

***Aegialitis rotundifolia***. Roxb. Fl.

Shrub without any aerial roots, trunk base broad due to basal fixed upright roots, stem swollen, spongy, bark dark grey, tap root sunken, stem straight, leaf simple, alternate, exstipulate, petiolate, lamina broadly ovate, slightly fleshy, dark green dorsal side shiny, entire, inflorescence-raceme, branched, peduncle long, flower bracteate, lanceolate, entire, complete, bisexual, pentamerous regular, calyx-sepals 5, gamosepalous, 5 lobes above, short adjoining at base, entire, green, valvate, inferior, corolla-petals 5, white, imbricate, entire, alternate to sepals, Androceium-Stamens-5, adhere to filament, extrose, basifixed, inferior Gynoceium-carpels-5, syncarpus, ovary oblong, one chambered, basal placentation, style 5, stigma absent.

## FAMILY: MYRSINACEAE

A large family with more than thousand species and characterized by free - central placentation.

**Fig. 7.** *Aegiceras corniculatum*

**GENERA:**

1. Fruit cylindric; seeds exalbuminous .................... ***Aegiceras***

**1.1** ***Aegiceras corniculatum*** **( L.)** (Fig. 7, Plate III)

Small tree or shrub, 2-6 m height, branches horizontally spreading, dense canopy; bark smooth dark grey. No aerial roots, leaves altering or spirally arranged, stipule absent, glabrous both sides, pale green above and glabrous below 5-7 cm long, 2.5-3.5 cm broad elliptic, apex rounded. Flowers fragrant, perfect white 1-2 cm diameter Sepals 5 free, petals 5 pointed end, corolla twisted. Fruit 5-8 cm.

## FAMILY: EUPHORBIACEAE

Plant with milky sap; ovary superior, 3 locular ovules collaterals, pendulous with ventral raphe.

**GENERA:**

1. Flowers in terminal spikes, regimes or panicle…………... **2**
2. Calyx deeply 3-partite; flowers in lateral axillary or terminal, spiciform, unisexual (dioecious or monoecious) or androgynous racemes or spikes ............……………… **1.** ***Excoecaria.*** **L.**

**1.** ***Excoecaria*****. L**

**SPECIES**

**1.** Halophyta tree ………..……… ***E.agallocha*** **L.**

***Excoecaria agallocha*** **L.** (Plate IV)

Medium tree upto 15 m height, partially deciduous, with poisonous milky latex, bark-grey. Without any aerial roots, but when tidal water current washed away the bottom soil then horizontal underground roots are exposed, look like snake-cable roots. Leaves spirally arranged, coriaceous or fleshy, simple, terete, petiole 1-2 cm long. Unisexual flowers in axillary inflorescence. Fruit 3 lobed, Schizocarp 1.5-2.0 cm diameter Seed length 0.3 cm.

## FAMILY: ACANTHACEAE

Family includes tropical herbs, shrubs or even small trees with zygomorphic, sympetalous usually conspicuous flowers irregular with 2 to 5 stamens. Prominent bracts and bractioles present; ovary bilocular, fruits 2 or more seeded capsule surrounded by hardened funicle.

***Acanthus*** **L.**

Plant (Fig. 8, Plate V) usually have spiny margined leaves, (yellow-green leaves) terminal inflorescence, flower with 2 bractioles and uniform anthers.

**Fig. 8.** ***Acanthus ilicifolius***

Open flower 3.5-4 cm long; corolla partly light blue or violet. Bractioles persistant, in fruit upto 1 cm long. Ripe fruit 2.5-3 cm long; seed approximately 10 mm in diameter. Inflorescence usually longer than 10 cm. Plants with spiny to very spiny leaves ……............................................…… ***A.ilicifolius* L.**

### *Acanthus ilicifolius* L.

*Acanthus ilicifolius* otherwise called a SEA HOLLY, a low sprawling or some what viny herb, scarcely woody, grows to a length of 2 m. Axes initially erect but reclining with age, branching commonly from older parts. Aerial roots from lower surface of reclining stems. Leaves decussate, usually with a pair of spines, glabrous, petiole short, blade gradually tapered below. Inflorescence terminal, forming bracteate spike. Each flower with bract, often caducous, lateral bracteoles 2, conspicuous and persistant. Calyx 4 lobed, the upper lobe conspicuous and enclosing the flower bud, lower lobe some what smaller, lateral calyx lobes narrow, wholly enclosed by upper and lower sepal. Corolla zygomorphic with a short tube closed by basal hairs; abaxial tip broadly 3 lobbed to entire, adaxial lobe absent. Stamens 4, sub equal, with thick hairy connectives. 2 celled anther, aggregated around the style. Ovary bilocular, 2 ovules in each locule, style enclosed by stamens, the capitate to pointed styma exposed, fruit capsule.

## FAMILY: TAMARICACEAE

Family consists of 120 species under 4 genera and characterized by shrubs or herbs with alternate simple inter-exstipulate leaves. Flowers solitary or in raceme.

### Genus: *Tamarix*.L.

The genus has about 90 species and most species are distributed in the coastal areas and *Tamarix gallica.L.* is the common species.

### *Tamarix gallica*.L. (Fig. 9)

Leaves simple, exstipulate, opposite decussate cat kin inflorescence, branched, flower pink violet, bisexual, regular, sepals 5 gamosepalous, valvate, petals 5, apical, acicular lobe, valvate, stamens 5, free, filament white, basifixed, Carpels 3, syncarpus, ovary superior, basal placentation, one chambered fruit capsule.

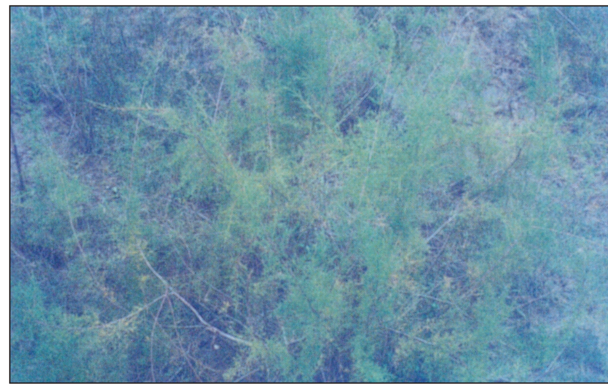

**Fig. 9.** ***Tamarix gallica***

## FAMILY: FABACEAE

Glandular and non-glandular hairs, epidemic of leaf may be papillose, stomata paracytic type.

### Genus: *Caesalpinia*

### SPECIES

1. Shoot apex is covered by gregarious spines, flowers unisexual by abortion …........**1. *C. bonduc* (L.)**

### 1. *Caesalpinia bonduc* (L.) Roxb

Climbing much branched shrub, gregarious spines present, nodes not rigid, internode having gregarious spines, woody, mature branches brown, having dense pubescent. Leaves compound, alternate, stipulate, paripinnate, axis glabrous, terete, lamine having short petiole, green, pulvinous, entire, reticulate venation. Raceme lateral or axillary, flower unisexual, irregular, male flower sepals-5, polysepalous, entire, blunt, petals 5, polypetalous imbricate, alternate to sepals. Stamens 10, free, dorsifixed anther extrinose Female flower: by abortion, carpels-2,bisexual, flowers, syncarpous, superior ovary, two ovules parietal placentation, style 1, stigma 1.

## FAMILY: ASCLEPIDACEAE

Asclepidaceae is closely related to other families like Oleaceae, Gentianaceae and Loganaceae but distinguished from others by the presence of gymnostegium.

***1. Sarciolobus globosus* Wall.**

Prostrate and climbing herb or shrub. Poorly branched presence of milky latex. Tap root – deep sunken. Nodes slightly ridged, but not jointed; in climbing condition branches become weak but in prostrate condition branches become thick, leaves simple, opposite decussate, exstipulate, petiolate, whitish green, mid-grooved, pulvinous, dorsiventral green, branched cyme, thick flower, whitish green, complete bisexual, regular, pedicillate, flower pentamerous, sepals-5, polysepalous, interior, imbricate, entire, alternate to petal. Petals-5 – gamopetalous, interior, ovate, pink-white, twisted, stamens –5 gynostegium attached to the stigma, corolla absent, filament short, anther bilobed, carpels-2 syncarpous, superior style 1 – terminal, stigma 2 – bipartite.

***2. Sarcolobus carinatus***

Climbing herb, nodes slightly rigid but not jointed, green grey leaves, simple, opposite decussate, existipulate, petiolate, yellowish green, terete, entire, acute, cup shaped or angled, distinct mid vein, reticulate venation, corymbose, peduncle unbranched, bract short, flower complete, bisexual, regular pedicellate, pentamous hypogynous. Sepals-5, polysepalous, inferior, imbricate, petals-5, gamopetalous, inferior, entire, scattered brown dot like spots on the outer surface of petals, stamens 5 – gynostegium attached to the stigma, filament short, carpels 2, syncarpous, superior ovary, axile placentation, style-1 terminal, stigma 2, globose.

**FAMILY: BORAGINACEAE**

Family consists of 7 genera and 2000 species.

**Genus : *Heliotropicum.* L.**

These species grow in the salt crusted soil and very often grow in highly saline soil.

***Heliotropicum curassavicum.* L.**

Prostrate, much branched spreading herb, leaves simple, exstipulate, opposite decussate, lanceolate, inflorescence helicoid cyme, flower bisexual, regular, complete, sessile, sepal 5, polysepalous, inferior petals-5 gamopetalous, cylindrical tube below stamens-5 epipetalous, filament very short, anther bilobed, carpels 2, syncarpous, ovary superior, 4 chambered, one ovule in each chamber, axile placentation, style 1, stigma absent.

***Family : Chenopodiaceae***

Chenopodiaceae characterized by having fleshy habitat. This family has about 120 genera and 1,400 species distributed throughout the world.

**GENUS : *Suaeda.* Forsk.**

Cosmopolitan distribution, characterized by halophytic herbs with fleshy leaves and dense cymes.

**SPECIES**

**1a.** leaves broad, green, style-2, seeds usually horizontal ……..**1. *S. maritima.***

**1b.** leaves semi-terate, green but reddish after maturation

Styles –3, seeds erect …...................…………… ………………..…… **2. *S.nudiflora***

**1. *Suaeda maritima*. Dumort**

Leaves simple, alternate, exstipulate, sessile, succulent, green. Spike at leaf axis, small flower. Flower bisexual, complete, regular, sessile, hypogynous, tepals-5, polypetalous, imbricate, acute, succulant. Stamens 5, free basifixed, anther bilobed, carpels 3, Syncarpous, ovary superior, single chambered with single ovule, basal placentation. Fruit drupe.

***3. Suaeda nudiflora* Roxb** (Fig. 10)

Prostrate herb having erect branches, internode not rigid, leaves simple, alternate, exstipulate, green, but after maturity it becomes red. Spike at least axis, flowers: bisexual, complete, regular, tepals-5, polytepalous, imbricate, fleshy, green stamens 5, free, white, anther bilobed, carpels 3, syncarpus, ovary superior, single chambered, single ovule, basal placentation. Stigma-0.

**Fig. 10.** ***Suaeda nudiflora***

**FAMILY: ARECACEAE**

The family is characterized by berry or drupe and in case of drupe the endosperms usually united to one seed.

**1a.** Unbranched, caudex palm, single spathe, capsule 3 united, fruit small upto 1.5 cm long. ………………………………….……………. **2 *Phoenix* L.**

**1b.** Unbranched, rhizomatious palm several spathe, carpels 3, aggregate. Fruit medium upto 12 cm long. ............................................. **1 *Nypa* Steck.**

***1. Nypa fruticans*** (Thumb) Wurmb (Fig. 11)

Dichotomously branched, rhizomatous stem, underground, fibrous roots, no aerial roots, leaf base spongy, looks like sunken coconut plant. Leaves pinnately compounded spirally arranged on the top, rachis stout, glabrous, shiny, green, isobilateral, distinct mid-vein, parallel venation.

Inflorescence, spadix on a long peduncle, cylinder shaped, spathe enclosed flowers, peduncle erect, male flowers gregariously on each peduncle, tapels-6 polytepalous in 2 whorls, entire, acute, stamens 3,united to form central column, anther bilobed, female flowers tepals 6, carpels 3, free, angular, but funnel shaped. Single ovule, basal placentation, style and stigma, fruits drupe, seeds grooved adaxially, ebracteate, peduncle bent and pendulous. Flowers: ebracteate, regular, unisexual, small. Sepals 4-5, gamosepalous, lobes ovate, entire acute petals absent. Male flower: Stamens 5 fused anther bifurcated, yellow entrose. Female flower bifurcated, yellow introse. Female flower carpels 4-5, ovary superior, single chambered, with one ovule, basal placentation. Fruit capsule.

**Fig. 11.** *Nypa fruticans*

***2. Phoenix paludosa*. Roxb. Hort.**

Unbranched perennial palm, fibrous roots, aerial pneumatothods are also developed, stem slender, cylindrical, unbranched, covered with dark fibrous sheath, distinct leaf scar, woody, leaves pinnately compound and rachis spirally arranged on the top of the stem, stem base mostly covered with spines of fibrous leaf sheath, rachis long, sheathing at base, leaflets bi-forms, apex spinous, distinct mid-vein, unicostate, parallel venation. Spadix spongy, yellow, glabrous; covered with the inflorescence at young state, flowers sessile, sepals-3, gamosepalous, valvate, petals 3, polypetalous, entire, thick, yellow, stamens 6, free, sessile, anther bilobed, yellow, extrose, female flower sessile, not showing gamosepalous, cup-shaped petals 3, imbricate, carpels 3, syncarpus, ovary superior, dumbel shaped, 1-seeded, style nil, stigma 3, short, fruit drupe.

**FAMILY: AIZOACEAE**

The family is characterized by xerophytic or halophytic herbs or shrubs, leaves often fleshy.

**1. *Sesuvium portulacastrum.* L.**

Prostrate much branched herbs, tap root system poorly developed, fleshy, spongy, nodes jointed, pink, short, leaves simple, opposite, decussate, petiolate, fleshy, spongy, distinct mid veins, solitary cyme, flower complete bisexual, regular, pedicillate, pink, sepals-5, polysepalous, imbricate, entire, fleshy, corolla absent, stamens numerous, free, basifixed, anther bilobed, carpels 3, syncarpous, ovary 3 chambered, style-3, stigma 0, fruit capsule.

**FAMILY : SOLANACEAE**

Solanaceae has about 85 genera, including 2,200 species.

***1. Solanum trilobatum.* L.**

Trailing with prickly hooked, shrubs, grow on bushy dry soil, nodes and inter-nodes not rigid, inter-nodes tapering towards end, leaves, simple, exstipulate, petiolate, entire round, inflorescence: corymbose, raceme, flowers: bisexual, regular, complete, violet green, hypogynous, sepals-5, polysepalous, entire, imbricate; petals-5, gamopetalous, bell shaped, ovate, entire, violet, stamens-5, epipetalous, soft, basifixed, anther yellow, carpels-2, syncarpus, fleshy, axile placentation, style-1, stigma absent.

FAMILY**: MELIACEAE**

**Genus: *Amoora***

***Amoora* (*Aglaia cucullata*)**

Medium tree, leaves compound, leaf let 2-4 pairs and an old one opposite, oblong, elliptic, sepals short round, petals-long, staminal tube shorter than petal, ovary stalked.

**FAMILY : POACEAE**

**Genus: *Myriostachya*. Hook**

***Myriostachya wigtiana* (Nees ex steud) Hook**

Clums tufted, erect, stout, sheathed, sometimes floating with long branched roots, simple, leaf blade broad, serrated, finely acuminate, inflorescence panicle whorled flowering, spikelets 4-8 flowered, pedicels short.

**FAMILY : PTERIDACEAE**

A large family of true ferns, their memebrs having sporongia covering the undersurface of pinna.

***Acrostichum* L.**

Rhizomatous fern, (Fig. 12, Plate VI) common in mangroves, axis horizontal or erect pinnate leaves upto 3m long, with a terminl leaflet, rachis rounded and smooth below scales on petiole base not having a prominent scar, plant axis horizontal, branched young leaves red in colour………..… ***A. aureum* L.**

**Fig. 12. *Acrostichum aureum***

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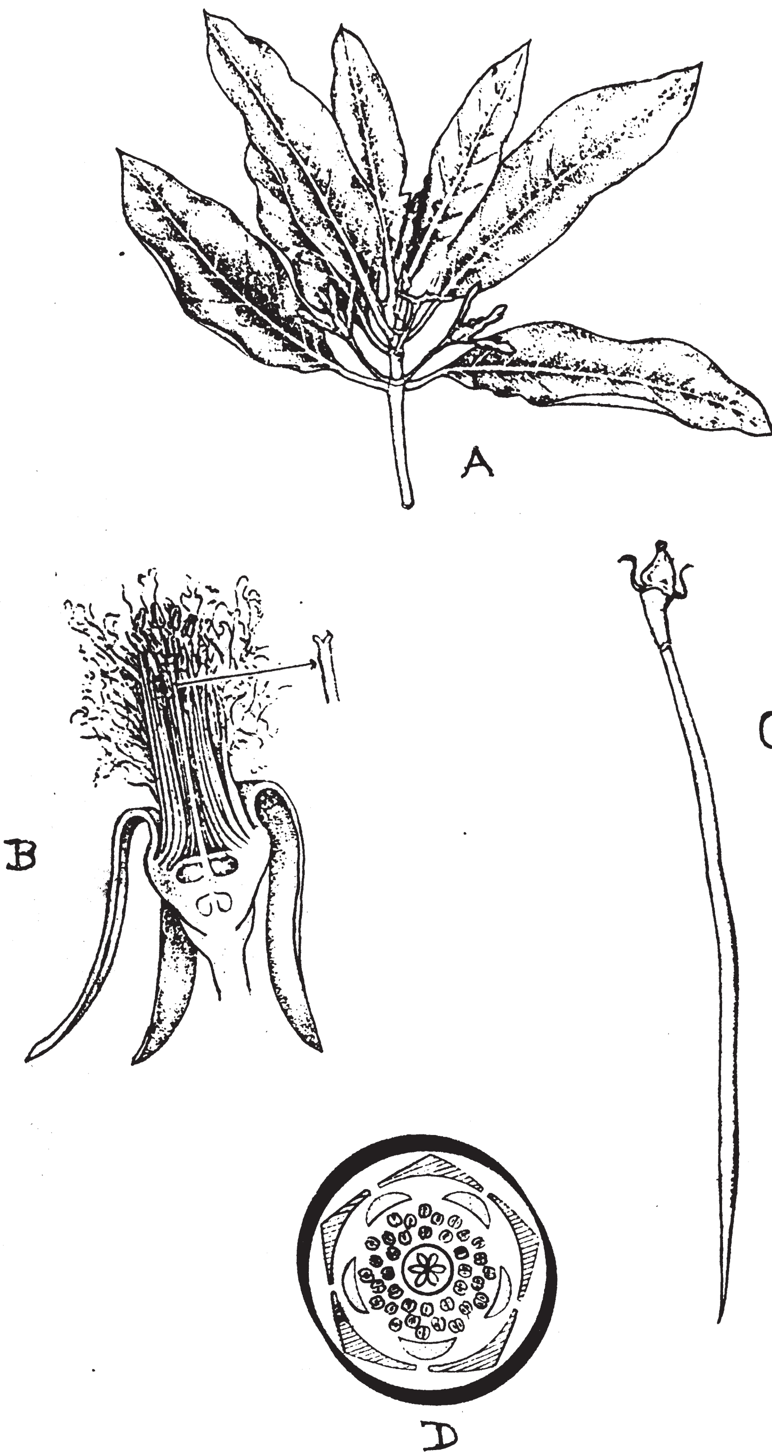



**Plate I. *Kandelia candel***
(A) Shoot with flowers, (B) L. S. of flower, (C) Mature detached seedling, (D) Floral diagram

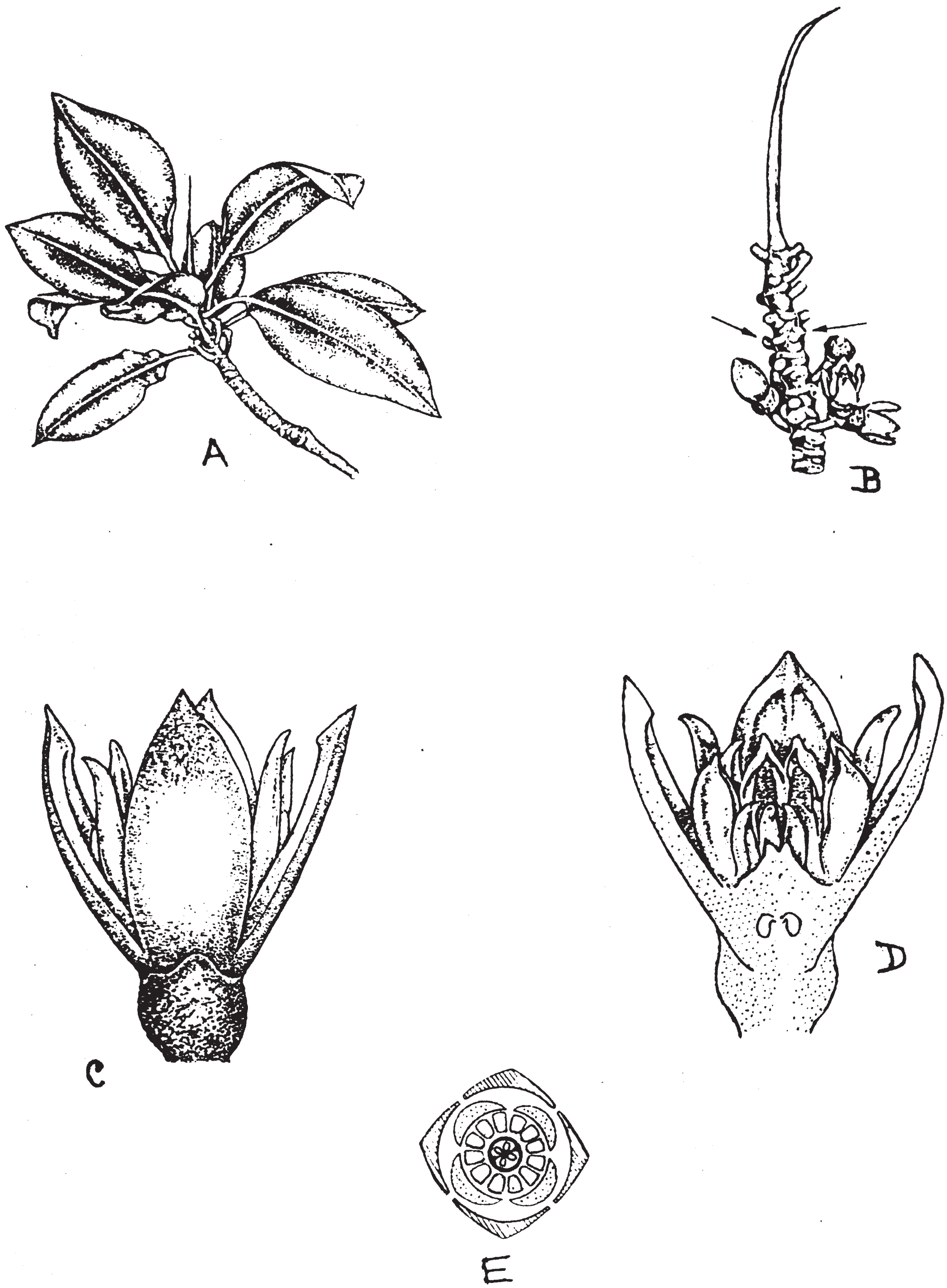



**Plate II.** ***Rhizophora apiculata***
(A) Shoot with inflorescence, (B) Twig with flower, (C) Entire flower, (D) L. S of flower, (E) Floral diagram


**Plate III.** ***Aegeiceras corniculatum***
(A) Entire plant, (B) Flowering clusters on shoot, (C) Opened flower, (D) L. S. of flower, (E) Floral diagram

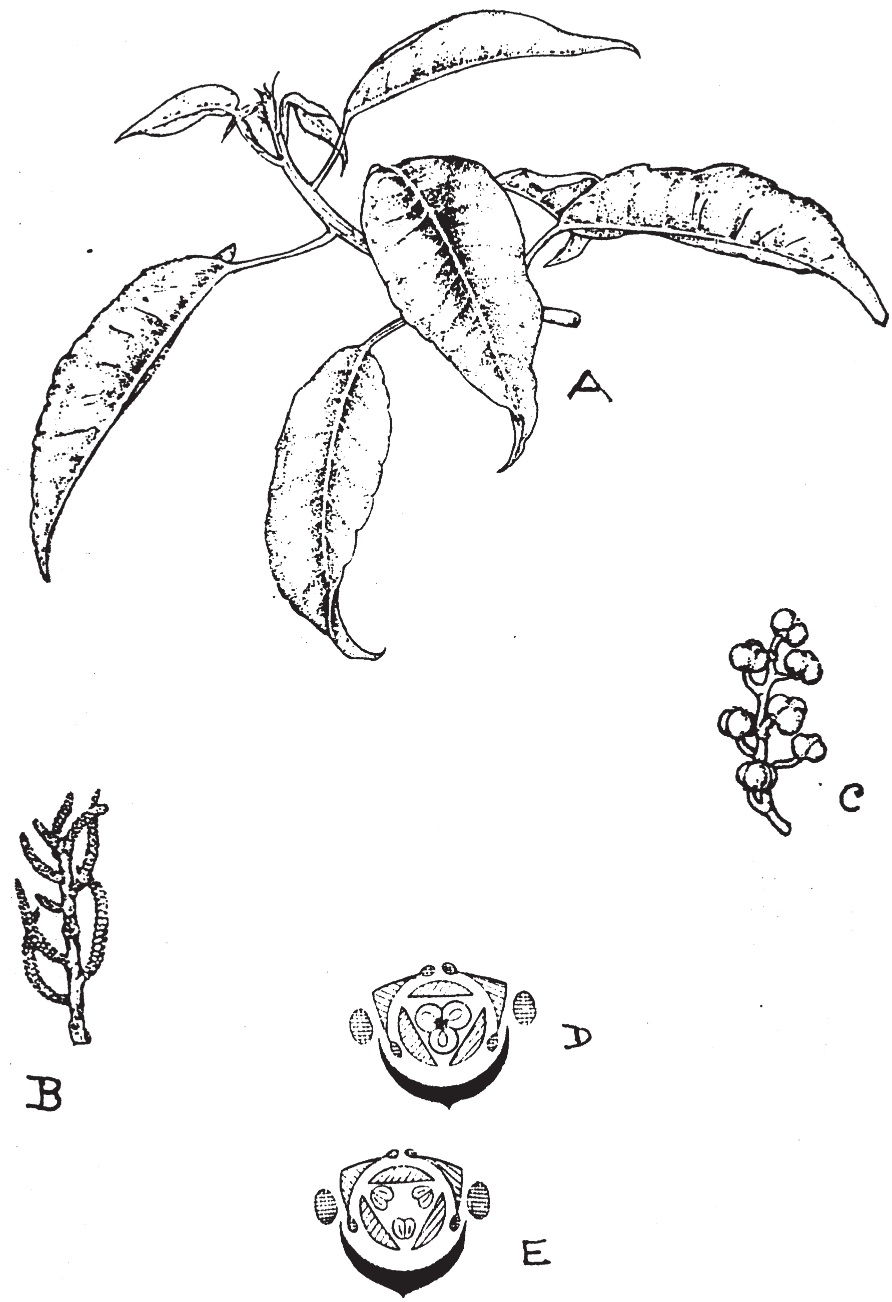



**Plate IV.** ***Excoecaria agallocha***
(A) Shoot, (B) Immature male spikes, (C) Immature fruits, (D) Floral diagram of male flower, (E) Floral diagram of female flower

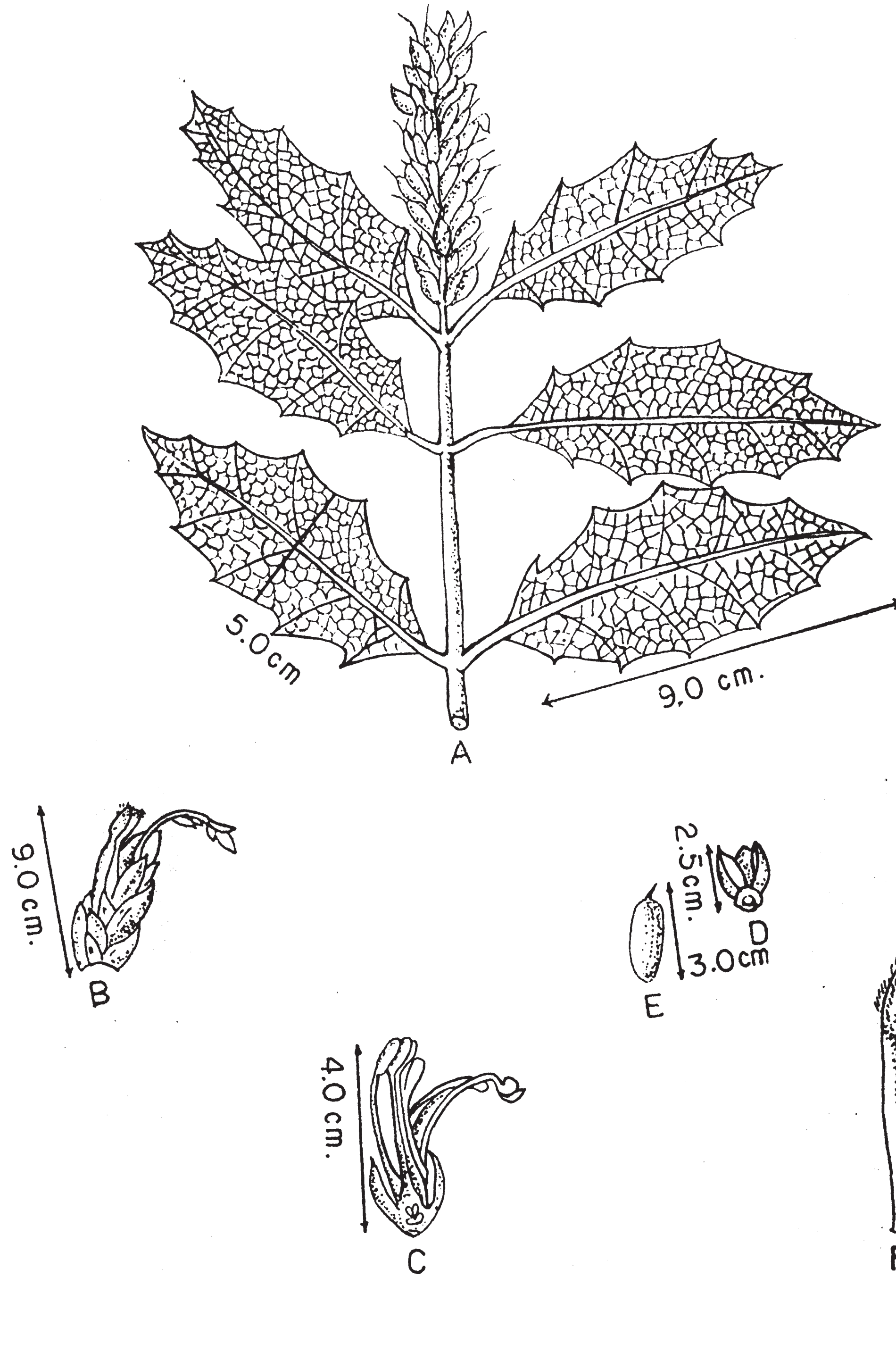



**Plate V.** ***Acanthus Ilicifolius***
(A) Habit with flower, (B) Part of inflorescence, (C) L.S of flower, (D) Sepals, (E) Fruit, (F) Gynoecium

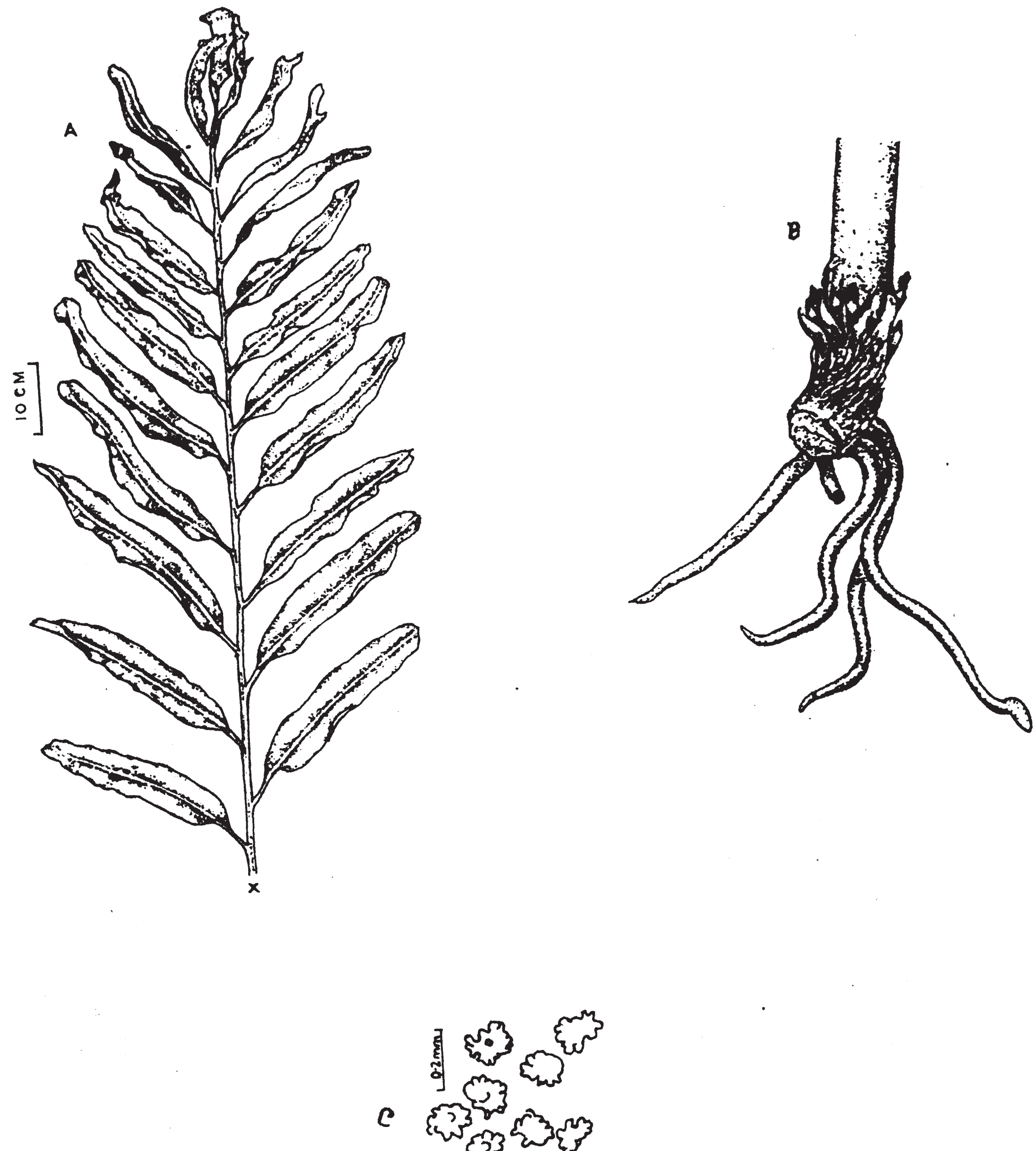



**Plate VI.** ***Acrostichum aureum***

(A) Upper part of frond, (B) Leaf base with adventitious roots and scale leaves, (C) Paraphyses

# Development of Herbarium for Mangroves

**P. Kaladharan and P. K. Jayasurya**

Mangroves are salt tolerant succulent plants. The main constraint in developing a herbarium of mangrove species is defoliation i.e., withering of leaves from the stem during pressing. This can be overcome by using proper fixatives.

**Procedure**

Select a healthy twig of mangrove species bearing not less than five leaves and flower and or fruit. Cut the selected twig, tie a tag bearing specific number, put it in a polythene cover. Add 15 to 20 ml of fixative (described at the end) so as to soak the entire twig. Mix them thoroughly and store air-tight. Details such as name of the plant, location, latitude, longitude, habitat, habital etc. can be written in a field diary against each tag number.

In the laboratory the fixed samples spread on a blotting paper or ordinary newspaper to absorb moisture. Keep one of the leaves showing the ventral surface while others show the dorsal view. Cover it with another sheet of paper and keep it under a Herbarium Press. The herbarium press is made of two wooden plants (50 x 60 cm) bolted together with wing-nuts on four corners so that twigs wrapped with absorbent paper can be pressed tightly with the wooden planks on either side. The absorbent papers have to be changed frequently to hasten drying.

The press-dried twig is pasted on a white herbarium sheet made of thick paper or thin white board (A3 size) at the centre. Right corner of the herbarium sheet should contain the details of the specimen recorded in the field.

The fixative solution is prepared by mixing the following ingredients and stored airtight

| | | |
|---|---|---|
| Ethanol | - | 500 ml |
| Water | - | 300 ml |
| Formaldehyde | - | 100 ml |
| Acetic acid | - | 50 ml |

The advantages of the fixative are :

Prevents withering of foliage and protects the specimen from fungi.

# MANGROVES

## Unique Ecosystem with rich Biodiversity, a National Wealth






**1. Mangrove during High Tide.**

**2. Typical Mangrove Plants. *Rhizophora mucronata* in the middle flanked by *Rhizophora apiculata***

**3. *Xylocarpus granatum* with fruit -Largest Mangrove fruit.**

**4. *Pandanus* with fruit- Leaves for mat fabrication.**

**5. *Acanthus ilicifolious* with flower.**

# Plankton - Methods for Study

**K. Vijayakumaran**

## Collection of samples

Standard plankton net is the most commonly used apparatus for collection of plankton (IOE- Standard net has 1m$^2$ mouth and mesh width of 300 µm). It comprises a cone of bolting silk (or equivalent material) mounted on a ring or hoop to which are attached three thin rope bridles spliced to a small ring by means of which the net can be shackled to a towing rope or warp (Fig.1). A weight is attached to the warp to facilitate sinking of the net to the required depth and to keep horizontal opening. Horizontal or oblique haul is commonly employed though vertical haul can also be made as desired with suitable change in the attachment of weight.

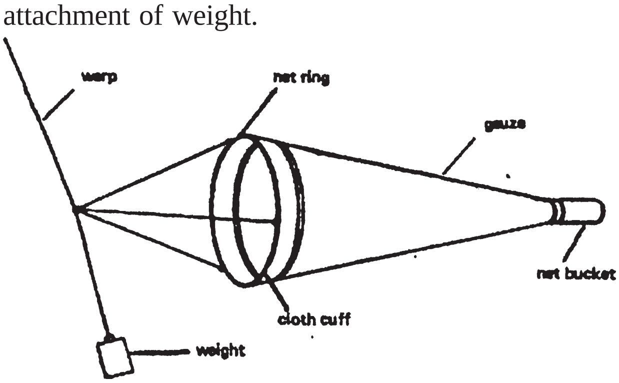



*Fig. 1. Standard Net*

A standard net dragged at 1-1.5 knots for ten minutes would ensure qualitative sampling. For quantitative assessment, it is very important to know the volume of water filtered through the net for assessing the quantity of plankton in unit volume. A calibrated flow meter can be attached to the mouth (a little behind the front) of the net, positioning exactly at the middle. If one digit reading of the flow meter is equal to d meter of water flow, then the volume of water filtered can be calculated at as:

**Volume (m$^3$) of water filtered** $V = \pi r^2 d \times f$

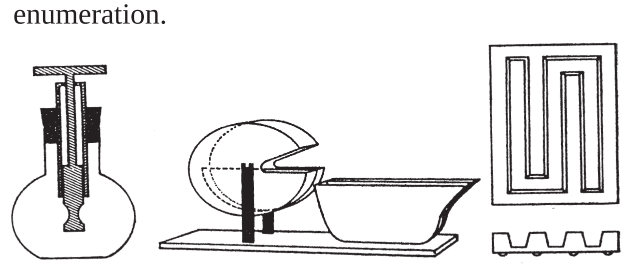
Where, ***r*** is the radius in meter of the net opening and ***f*** is the flow meter reading (final reading minus initial reading)

## Preservation of sample

Although examination of live plankton has many advantages, the facilities available may not permit long storage of live specimen. Therefore, the sample must be fixed using neutral formaldehyde sufficient to bring the concentration to about 4 % in the final preserved fluid. This can be done by adding 20 ml of 40% formalin in 200-ml of water containing plankton. Use screw capped jars, preferably plastic, for storage of the preserved plankton with label carrying relevant information

## Taking measurements and counts

Larger organisms (macroplankton) which are usually present in small numbers can be identified and enumerated examining with naked eye. The microplankton can be identified and enumerated only under a dissection microscope. Their numbers being far too many, the sample can be thoroughly mixed and small aliquot portions can be taken for examination and counting. Wherever possible devices such as Stempel Pipette (Fig.2) or Folsom Plankton Separator (Fig.3)can be conveniently used for accurately taking aliquots of sample and a Bogorov Counting Tray for properly counting of organisms (Fig.4). The enumerated organism must be recorded in a systematic order (see Appendix-1). Individual items difficult to identify must be kept in separate specimen tubes properly labeled for future identification. Organisms of special interest also can be separated for measurement, identification and enumeration.



2 3 4

*Fig. 2. Stempel pipette, (3). Flosom plankton separator, (4) Bogorov counting tray*

The volume of plankton can be determined by the displacement method. Extremely large specimens such as jellyfish have to be separated before taking measurements in order to avoid unusual values. First the total volume (ml) of the concentrated plankton plus preserving fluid (v1) is measured. Then the plankton is filtered off by suitable filter and the volume (ml) of the filtrate (v2) is measured. The final representation of plankton volume would be as:

**Plankton Volume (ml m-$^{3}$) or = ml/m$^{3}$ =**

where V is the volume of water filtered throught the net

The filtered plankton can be dried at $50^{0}$ C in a desiccator inside an oven and then weighed rapidly. Alternatively (a more acceptable method) the fresh sample before addition of formalin can be divided into two equal portions, one portion can be preserved for subsequent sorting and counting and the other portion can be washed filtered and dried for taking weight.

### Nannoplankton

The nannoplankton, which consists predominantly of small flagellates, can only be obtained quantitatively from bottle samples. Though the quantity of sample has to be decided depending up on the density of plankton, concentration techniques such as sedimentation (Utermöhl technique) can be conveniently followed.

Add 3 ml of Lugol's Iodine to one litre of the seawater sample, (see Appendix-2 for method of preparation) and allow standing for 24 hours in a measuring cylinder. After all the particulate matter had settled down to the bottom, siphon off the supernatant water taking care that the settled sediment has left undisturbed. The one litre sample may thus be reduced to about 60 ml. Use only clear glass bottles to store the sample (plastic bottles would take up iodine from the solution).

### Counting

Mix thoroughly the settled sample and take aliquot (one-ml) of the sample and count using a Sedgwick-Rafter counting chamber under binocular microscope for enumeration. Qualitative and quantitative enumeration have to be done by counting replicate aliquots and the average can be taken for estimating the cell count in one litre. In the case of chain forming species, the number of chains can be counted. The cell count of different species (ni) per litre can be calculated at by the following method.

Number of cells per litre of **i$^{th}$** species,

Where, is the average count of ith species, 'V' the volume of sample and 'v' the volume to which the sample was reduced.

The total plankton cell count (N) per litre can be estiamted by $N = \sum_{i=1}^{s} n_i$

### Haemocytometer

Alternatively, when the plankton cells are numerous and less than 30 µ in size, the cell counting can be done using a haemocytometer. The haemocytometer with an improved Neubauer ruling must be rinsed clean and dried. The face of the counting chamber is composed of two girded surfaces separated by canals. The coverslip has to be placed on the support bars along the canals. A drop of homogeneously mixed algal suspension (of 60 ml settled portion mentioned above) is delivered from a Pasteur pipette by touching the pipette tip to the edge of the cover slip where it hangs over the V-shaped loading port. Both the chambers must be loaded to seat the coverslip properly. If the algal suspension overflows either side, the chamber must be cleaned and refilled.

Each half of the haemocytometer surface contains nine large grids. Only those algal cells, which fall within the four large corner grids (numbered 1 to 4), are to be counted. Each larger corner grid is further divided into 16 small squares. Moving systematically back and forth across the squares, a minimum of 200 algal cells may be counted in as many grids as necessary. Cells falling on the border are counted if at least half the cell is within the square, taking necessary caution not to count the same cell twice. The number of algal cells per ml can be arrived at by dividing the number of cells counted by the larger corner grid area covered for counting multiplied by 10,000. For example, if one and a half large corner grids (or 24 small squares) were covered to count 300 cells, the cell density is equal to 2 x $10^{6}$. In general the ultimate cell count per litre can be worked out by the formula:

$$\text{Number of cells per litre} = \frac{n}{g} \times 10000 \times \frac{v}{V}$$

Where, n is the number of algal cells counted, g the number of corner grids covered, 'V' the volume of sample and 'v' the volume to which the sample was reduced after settlement.

Different ecological indices can be worked out using formula given in Appendix 4.

**A simplified method for counting phytoplankton is 'microtransect method' (Vollenweider, 1974).**

It is described by Lackey (1938) and further explained by Vollenweider, 1974 in IBP Handbook No. 12 has the great advantage, that it does not requiere specialized instruments. It is indeed capable of providing more or less precise results as those of advanced methods, if increase the number of drops/ sample enumerated.

The microtransect is the area of field of visions seen through a microscope when the slide is moved in a direction by the help of a stage meter. A path is observed comprising several field of visions from one end of a square / rectangular cover slip / glass to the other end. If a measured amount of phytoplankton sample can put under the cover glass, the transect represents a known volume of sample and number of individuals per ml can be calculated. It can be later converted into no/litre or $m^3$ depends on the method of sample collection.

The sample must be small to fit entirely under a cover glass. Such a quantity may be invariably one drop from a medicine dropper of ordinary diameter. Chemical volumetric pipette should not be used because of very narrow opening. The dropper must be caliberated. The sizes of drops of samples fall freely from dropper are almost uniform. The dropper should be held vertically and time to be given to from each drop in full size.

Measure the width (maximum diameter of field of vision & $\frac{d}{2}$ is the radius) of the high power field with a stage micrometer after caliberation with ocular meter. The area of one field of vision can be calculated by the formula $\pi r^2$. Every transect will give a fraction of the area under the cover slip and a definit quantity of sample.

Mix the sample thoroughly to distribute evenly the plankton before taking the drop. Then carefully deliver a drop to a clean slide and cover with an appropriate cover slip. The sample should not go beyond the margins of coverslip. One can achieve the general / uniform distribution of organisms by practice and can be checked by low power also. It is better to use the same eye piece, objective and microscope until counting of all the samples in a single programme/ project.

Move the slide, so that a transect is examined across the middle of the cover glass and count the plankton. Record and count several separate transect. Count another drop from same sample and if results are varying much, count a third drop. Subsampling or taking drop must be done very carefully.

Calculation

$$\text{Total number / drop (can be standardised as 0.1 ml)} = \frac{\text{Area of covergalss}}{\text{Area of transect}} \times \text{No. of counts / transect}$$

The value can be converted later into no./ltr. or $m^2$ or $m^3$ depends on method of sampling.

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# Micro Algae

**C. P. Gopinathan, P. K. Jayasurya, M. Kaliamoorthy and Sunirmal Giri**

The present work pertains to the micro flora of selected mangroves of India. The littoral diatoms are found to occur in the sediment as well as attached to the decaying leaves of mangrove plants. Few of them are true plankton, which are brought to the mangroves during high tide.

Altogether 48 genera and 2 general of blue green have been described under which 80 species have been found in the Indian mangroves. The systematic position of the common littoral diatoms is given below (genera only):

| | |
|---|---|
| Class | Bacillariophyceae |
| Order | Centrales |
| Sub order | Discoideae |
| Family | Coscinodiscae |
| Subfamily | Melosirineae |

1. Genus : *Melosira* Agardh

Cells forming closely fitting long chains, disc shaped, papilla like structures at the border of the valve, those of the neighbouring cell fitting into the depression between this papillae and thus helps to hold together. Chromatophores numerous, disc shaped. Length of valve 20-30µ.

2. Genus: *Stephanopyxis* Ehrenberg

Cells cylindrical with arched end faces; valves convex, number of cells joined together by their spines to form chain, spines numerous arranged in a ring and enlarged at the base. Diameter of the cell 50-110µ.

3. Genus *Podosira* Ehrenberg

Cells round cylindrical, united to form short chains, attached to decaying leaves. Cell wall areolated, in valve view the areolate arranged in straight oblique lines. Girdle composed of inter-calary bands. Length 42-50 µ.

4. Genus *Cyclotella* Kutzing

Cells discoid, rectangular, valve with two distinct surface areas, the central portion coarsely punctate,valve surface striated. Diameter of the valves 40-45µ.

| | |
|---|---|
| Family | Actinodisceae |
| Subfamily | Actinoptichineae. |

5. Genus : *Skeletonema* Greville

Frustules weakly silicified, lens shaped with rounded ends, forming long slender chains with the aid of marginal spines which run parallel to the axis of the chain. Chromatophores two plates which are at times dissected. No visible structures on the valve. Diameter of the cell 10-15µ.

6. Genus: *Thalassiosira* Clev

Cells disc shaped forming a colony enclosed in muscilage. Valves weakly silicified, chromatophores numerous disc shaped. Structure on the valve not visible. Diameter of the cell 30-55 µ.

| | |
|---|---|
| Family | Actinodisceae |
| Sub Family | Asterolamprineae |

7. Genus: *Asteromphalus* Ehrenberg

Cells slightly convexed, valves ovate, middle field exentric, sector lines of middle unbranched, hyaline rays 7-8, one slightly narrower reaching margin of the valve. Rays slightly corved. Border segments aerolated in 3 line system. Length of valve 35-60 and breadth 30-50 µ.

| | |
|---|---|
| Family | Eupodisceae |
| Sub Family | Aulicodiscineae |

8. Genus *Actinoptychus* Ehrenberg

Cells discoid, valves divided into 6 sectors, alternatively raised and depressed. Central area hexagonal, hyaline. The raised sectors posses a short blunt process in the middle near the margin. Valve surface strongly areolated. Depressed sectors without processes. Diameter of valve 50-60µ.

Family Biddulphieae

Subfamily Biddulphineae

9. Genus *Biddulphia* Gray

Valves elliptical with swollen margins, strongly sculptured with a few ribs inside. Two blunt, rounded processes at the corners, areolations both valve and girdle. Cells forming long or short chains, by attachment with mucilage pads at blunt end of their processes. One of the common forms found in mangrove habitats when salinity is high. Cell length from 60-90µ.

Sub Family Triceratineae

10. Genus *Lithodesmium* Ehrenberg

Cells forming long chains. Valve plane triangular, corners rounded. Valve with a small spine at the center. Sides of valve measuring 40-50µ, membrane punctate.

11. Genus *Triceratium* Ehrenberg

Cells box like with three-cornered valve plane and short per valve axis. Sides of valve slightly convex, the corners rounded. Blunt processes present. Cell wall strongly sculptured, areolate. Areolae in regular rows, almost of the same size. Chamber openings clear, girdle band areolated, punctate. Length of valve 65-150µ.

Order Pennales

Suborder Araphideae

Family Fragilarioideae

12. Genus: *Bellerochea* Van Heurck

Cells flat, forming ribbon-like chains, weakly silicified, valve with a rudimentary central knob and punctate in the margin. Apertures slit-like, closed in the middle by rounded valves. Chromatophores numerous, disc shaped, Length of the cell 50-78 µ.

Family Hemiaulineae

13. Genus : *Cerataulina* Paragalle

Cells cylindrical, elongated along per valvar axis, forming long chains. At the margin of the valve two short cylindrical processes with hair like spines on them. Apertures small. Structures on valve not clear. Apical valve measuring 12-26µ.

14. Genus *Aulicodiscus* Ehrenberg

Cells disc shaped, valves without radial elevations, three distinct processes of the valve, knob like, placed equally apart. A number of pore canals a little within the border. Chromotophores several lobed disc with a central pyramid. Diameter of the cell 74-114 µ.

Sub order Solenoideae

Family Solenieae

15. Genus : *Shroederella* Pavillard

Cells cylindrical with more or less slightly convex, valves depressed in the middle, cells bound in chains. Valves with a crown of spines in the center, a spine-like pore canal present. Diameter of the cell 14-39µ.

16. Genus: *Chaetoceros* Ehrenberg

Cells cylindrical forming straight chains. Tiny spines at the center of the valve. Terminal setae strongly divergent, thicker than the rest. Outer setae of the end cells different. Chromatophores numerous. Length may vary from 35-75 µ.

17. Genus *Rhabdonema* Kutzing

Cells in girdle view ribbon shaped with hyaline rounded corners forming more or less long bands. Intercalary bands numerous, valves linear, transversely striate, valve view not observed. Length of valve 80-120µ.

18. Genus *Grammatophora* Ehrenberg

Frustules quadrangular with rounded angles, septa slightly undulate, valves linear-oblong, several times constricted in longer individuals, broad and widened in the middle, ends capitulate 20-70µ long and 10-15µ broad, striae not clearly visible.

19. Genus *Licmophora* Agardh

Frustules in girdle view cuneate with strongly rounded angles. Lower end attached to mucous stalk, cells forming colonies. Septa projecting into the cell. Valves lanceolate with margins, sub-parallel towards the apex, narrowed and elongated towards the base. Pseudoraphe distinct. Length of the cell 30-75µ and breadth 12-15µ.

20. Genus *Climacosphenia* Ehrenberg

Frustules on short branched mucilage stalks, epiphytic forming colonies, narrow with upper margin rounded at the angles, or sub-quadrate. valves clavate, rounded at the apex, elongated below transversed longitudinally by two parallel lines, cell length 90-800µ and breadth 20µ at the top and 7-10µ at the base.

21. Genus: *Climacodium* Grunow

Cells even, flat, forming very long ribbon-shaped chains, in girdle view with small linear middle part at the poles of the apical axis with more or less slender processes. Intercalary ban absent. Membrane structures not visible. Apical axis 100-160µ in length.

22.Genus: *Streptotheca* Shrubsole

Cells square to rectangular, membranaceous forming long chains, which are at time twisted on its own axis. Chromotaphores numerous, disc shaped.

| | |
|---|---|
| Order | Pennales |
| Sub Order | Araphidineae |
| Family | Fragilarioideae |

23.Genus: *Thallassiothrix* Cleve and Grunow

Frustules free, thread like often slightly curved, valves linear cells forming zig- zag chains, slender, both tendency in the same chain. Length: 90-210 µ.

24.Genus *Rhaphoneis* Ehrenberg

Frustles lanceolate, inflated at the center, 20-40µ long, valve areolated, close together. Pseudoraphe narrow in the center and slightly dilated at the pole. The cells grow attached to particles or dirt on other algae.

25.Genus *Synedra* Ehrenberg

Valves linear, gradually attenuate to the rounded ends,140-300µ long, 20-35µ broad, cell wall porous, pores enclosed inside and appearing as small openings. Valves with 3 longitudinal ribs hence as four series of openings. Outer membrane finely areolate-punctate. Between two ribs double series of areolae.

| | |
|---|---|
| Suborder | Monoraphideae |
| Family | Acanthoideae |
| Subfamily | Coconeideae |

26.Genus *Cocconeis* Ehrenberg

Cells elliptic, 20-40µ long and 15-20µ broad, raphe less valve with three well defined hyaline areas demarcated by striated bands. Valve with raphe, the striae are radial, raphe sigmoid, axial area narrow dilating into a very small central areas.

Sub Family *Achnanthaceae*

27.Genus *Achnanthes* Bory

Valves lanceolate with scarcely drawn out rounded ends. The cells35-45µ and 1-16µ broad. Raphe-less valve with robust transapical ribs, perpendicular to the middle lines, crossed by delicate longitudinal ribs. Pseudoraphe long, linear. Valve with raphe thread-like, axial area narrow, widened in the middle a little. Central area having a small cross band about half the valve breadth. Transapical strea radial and throughout.

| | |
|---|---|
| Sub Order | Biraphidea |
| Family | Naviculoidae |
| Sub Family | Naviculeae |

28.Genus *Mastogloia* Thwaites

Valves lanceolate with more or less constricted bluntly rounded ends, 20-22µ long and 10µ broad. Raphe straight, axial area very narrow, central area widened and connected to two small half lanceolate areas, together forming an "H" shaped figure. Transapical strreae fine, radial, 20-24µ. Loculi bigger in the middle, the outermost ones slightly smaller.

29.Genus *Gyrosigma* Hassal

Valves linear with slightly truncate and obtuse ends, 300-340µ long, 30-38µ broad. Raphe slightly excentric and somewhat flexciose. Central area small, oblique, with transverse and longitudinal striae equidistant.

30.Genus *Pleurosigma* Smith

Valves scarcely sigmoid, lanceolate, tapering from the middle to the sub-acute ends, 75-140µ long and 15-30µ broad, raphe slightly sigmoid and central.

31.Genus *Diploneis* Ehrenberg

Valves strongly with sub-elliptical ends,30-55µ long and 12-20µ broad and at the constriction 8-14µ broad. Central nodule with approximate horns. Transverse costa 9 in 10µ,crossed by equidistant longitudinal costae curved outwards in the middle of the valve.

32.Genus *Navicula* Bory

Valves elliptic, rhombic, elongated with acute ends,35-90µ long,axial area narrow, central area small, striated, radial. Widely distributed form in coastal and mangrove ecosystem.

33.Genus *Trachyneis* Cleve

Valves linear, lanceolate with obtuse ends, 55-220µ long and 12-22µ broad, axial area broad,truncate, not reaching the site. Transapical striae alveolate, longitudinal striae very fine.

34.Genus *Amphiprora* Ehrenberg

Cells strongly constricted, keel with hyaline margin. Junction line curved like a box. Cells 65-90µ long. Keel punctae forming obliquely decussating rows, striae curved, connecting zone with numerous longitudinal divisions.

35.Genus *Tropidoneis* Cleve

Valves membranaceous, lanceolate, acute, in girdle view slightly constricted, 125µ long and 20µ broad. Keel somewhat excentric striae not reaching the margin of the valve.

36.Genus *Amphora* Ehreberg

Frustules hyaline, weakly silicified, in girdle view rectangular, elliptical with slightly convex sides 70-95µ long, 32-55µ broad, intercalary bands numerous. Raphe with straight branches which run back from the central dorsal-ward. Axial area narrow, central area absent. Trasapical striae slightly radial, finely punctate.

37.Genus *Cymbella* Agardh

Cells linear, ventral margin straight, dorsal arcuate, raphe somewhat broad, axial area narrow, central area slightly dilated,striae radial, common form in littoral zone.

38.Genus *Bacillaria* Gmelin

Cells in girdle view linear and rectangular, united by their valves to form a mat like colony, the individual cells of which exhibit gliding movements in the living conditions. Valves linear. Spindle shaped in outline 112-120µ long and 7-10µ broad. Keel punctate and transapical striae fine.

39.Genus *Nitzchia* Hassal

Cells elliptical, linear. Slightly constricted to the middle extremities somewhat pointed, in valve view almost straight considerably diminished in size at the extremities and elongated, 80-300µ long, 15-20µ broad, keel punctate.

40.Genus *Hantzschia* Grunow

Cells narrowly rectangular in girdle view, elongated, narrow and slightly bent in valve view, sides almost straight, keel punctate, irregular, striated. Length of valve 70-78µ and breadth 18-20µ.

Sub Order Raphidiodineae
Family Eunotiaceae

41.Genus *Eunotia* Ehrenberg

Valves arcuate with the dorsal side well bent, narrow towards the ends, rounded striated, coarse, striated. Length of valve 60-70µ and breadth 15-18µ.

Family Epithemiaceae

42.Genus *Epithemia* Brebisson

Valves arcuate, apices more or less rostrate, capitate, dorsal margin rather flexed, coste, radiant, girdle view more or less strongly inflated in the median portion. Length of valve 75-60µ and breadth 15-20µ.

43.Genus *Podocystis* Bailey

Epiphytic diatom, attached to higher algae or decaying leaves of mangroves by means of short mucous stipe or pad. Valves broadly ovate or balloon shaped, having the lower end slightly flattened. Valve surface with a median pseudoraphe and transverse costae between which are two rows of areolae, alternatively arranged. Length of valve 100-110µ and breadth 60-65µ.

44.Genus *Isthmia* Agardh

Cells are united to form short chains, epiphytic form, valves elliptic without costae, but well developed girdle with two distinct poles, one short and other slightly big. Valve surface and girdle areolated. Length of cell 70-75µ.

Family Surirellaceae

45.Genus *Surirella* Turpin

Valves oval and reniform, radiating septa, reniform axial area, surface of valve hyaline, striae indistinct, length of valve 60-65µ and breadth 25-40µ.

46.Genus *Campylodiscus* Ehrenberg

Valves sub-orbicular, nearly circular, cannaliculate, equal in length, about one third of the radius of the valve central area punctate, arranged in radiating lines, interrupted by a linear median space. Length of valve 85µ and breadth 75µ.

47. Genus *Aulicus* Ehrenberg

Cells disc shaped with broadly elliptic valvar plane,long axis 45-50µ and short axis 40-42µ. Two hyaline ‘eye’ of 12µ in diameter present opposite to each other. Valves sculptured with strong radial ribs which became faint, towards the center. Valves radially striated, central area hyaline, more or less oblong with round structures.

48.Genus *Encyonema* Kutzing

Valves large, dorsal considerably inflated, ventral side with slight curvature, apices abruptly produced, obtuse and rounded, raphe straight with the medium ends, slightly areolated towards the dorsal margin surrounded by a hyaline zone. Valve surface striated. Length of valve 75µ and breadth 25µ.

| | |
|---|---|
| Phylum | Cyanophyceae |
| Class | Nostocales |
| Family | Oscillatoriaceae |

49.Genus : *Oscillatoria* Vaucher

Trichome single or forming a flat or spongy free. Swimming thallus, sheath absent, end of trichome pointed, bend like a sickle or coiled. Present in stagnant water bodies.

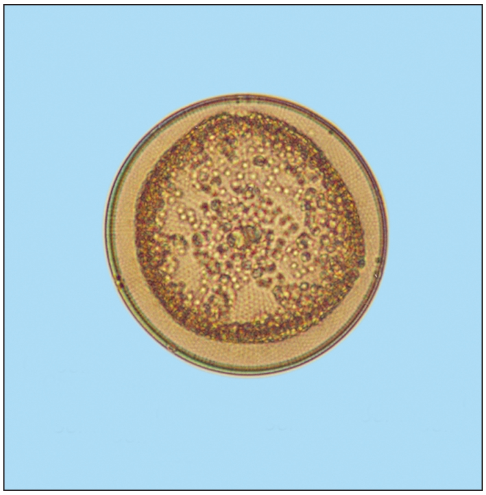
50.Genus: *Phormidium* Kutzing

Filaments forming a gelatinus or leathery stratum, sheath present, thin and colourless, trichomes cylindrical, apices attenuated, spirally coiled, apices with calyptra: Present in stagnant water bodies.

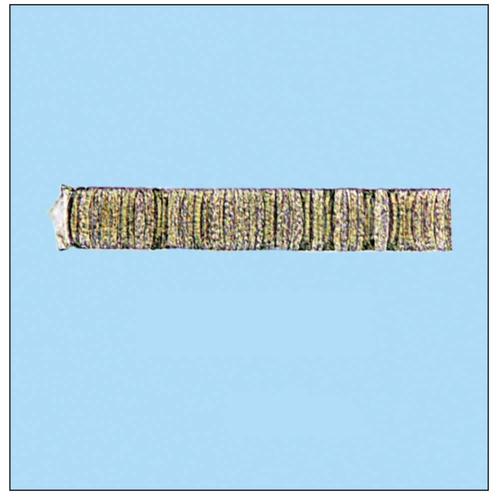
**Common green algae, blue green and macro algae occurring in Mangroves**

Due to the tidal influence and mixing of fresh and marine water in the mangrove ecosystem, several species of green, blue green algae and seaweeds enter in the mangrove waters. The common forms seen in mangrove areas are species of *Scenedesmus*, *Oocystis*, *Chlorella*, *Ulothrix*, *Cladophora*, *Oedogonion,* and *Chara*( all are Green micro algae) and species of *Spirulina*, *Anabaena*, *Nostoc*, *Oscillatoria* and *Lyngbya*( all are blue green algae) and species of macro algae are seaweeds comprises *Chaetomorpha*, *Enteromorpha* and *Ulva*.

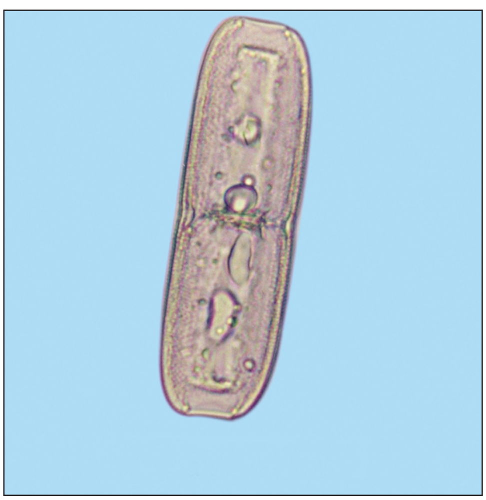
# Very common species of micro algae in the mangroves



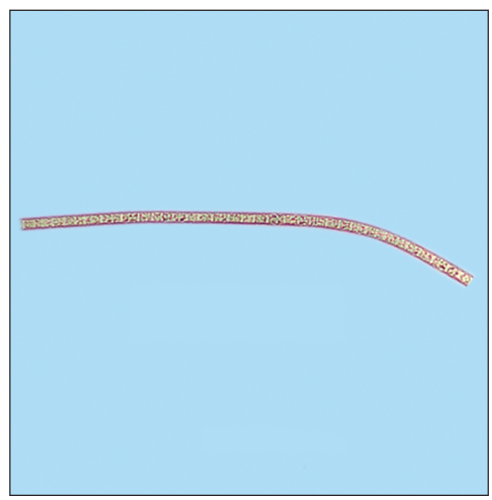
*Coscinodiscus excentricus* (valve view)



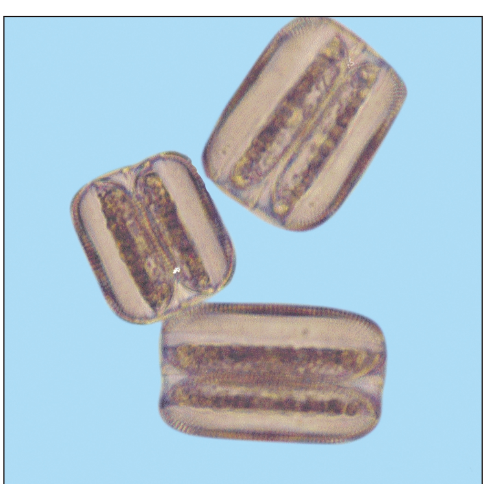
*Phormidium sp.*



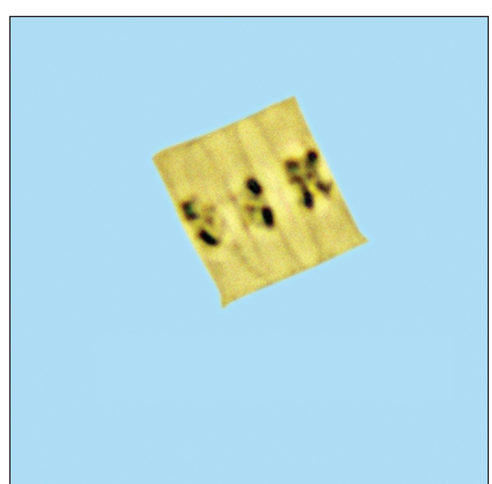
*Amphora decussata*



*Oscillatoria sp.*



*Coscinodiscus excentricus* (girdle view)



*Chaetoceros lorenzianus*

| | | | | |
|---|---|---|---|---|
| Fig. I | 1. | *Podosira montagni* | - | two cells in girdle view |
| | 2. | *Cyclotella striata* | - | valve view |
| | 3. | *Terspinoe musica* | - | gridle view |
| | 4. | *Aulicus sculptus* | - | valve view |
| | 5. | *Triceratium dubium* | - | valve view |
| | 6. | *Triceratium reticulatum* | - | valve view |
| | 7. | *Triceratium roberstianum* | - | valve view |
| | 8-10. | *Biddulphia pulchella* | - | girdle views |
| | 11. | *Biddulphia alternans* | - | girdle view |
| | l2. | *Biddulphia aurita* | - | girdle view |
| | 13. | *Biddulphia laevis* | - | girdle view |
| | 14. | *Biddulphia granulata* | - | girdle view |
| | 15-16. | *Lithodesmium undulatum;* | - | valve and girdle view |
| | 17. | *Isthmia nervosa* | - | girdle view |
| | 18. | *Isthmai enervis* | - | girdle view |
| | 19. | *Rhabdonema mirificum* | - | valve view |
| | 20. | *Striatella unipunctata* | - | valve view of two cells |
| | 21. | *Grammatophora undulata* | - | cells in girdle view |
| | 22. | *Licmophora abbreviata* | - | girdle view |
| | 23. | *Licmophora ehrenbergii* | - | girdle view |
| | 24. | *Licmophora flabellata* | - | girdel view |
| | 25. | *Licmophora gracilis* | - | girdel view |
| | 26-27. | *Licmophora juergensii* | - | girdle and valve view |
| | 28. | *Synedra crystallina* | - | girdle view |
| | 29. | *Synedra ulna* | - | valve view |
| | 30. | *Licmophora paradoxa* | - | girdle view |
| | 31-32. | *Climacosphenia moniligera* | - | girdle and valve views |
| | 33-34. | *Climacosphenia elongata* | - | girdle and valve views |
| | 35. | *Rhaphoneis amphiceros* | - | valve view |
| | 36. | *Synedra superba* | - | valve view |
| | 37-38. | *Synedra pulchella* | - | valve view of a cell and colonial habit |
| | 39. | *Podocystis adriatica* | - | valve view |
| | 40. | *Cocconeis scutelum* | - | valve view |
| | 41-42. | *Cocconeis placentual* | - | ventral and dorsal valve views |
| | 43. | *Cocconeis littoralis* | - | ventral valve view |
| | 44. | *Cocconeis pseudomarginata* | - | valve view |

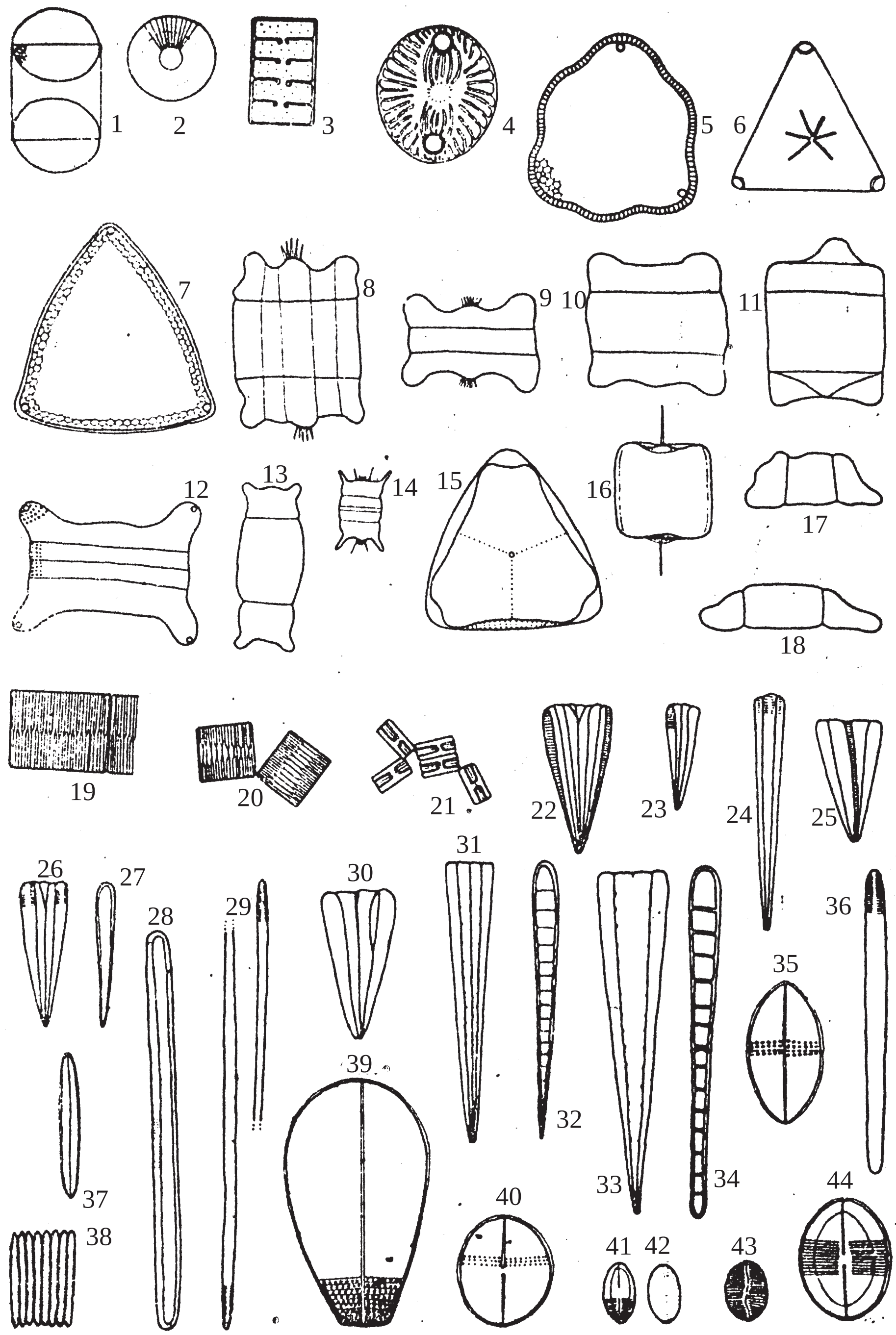

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Fig. I

| | | | | |
|---|---|---|---|---|
| Fig. II | 1. | *Achnanthes brevipes* | - | girdle view |
| | 2-3. | *Achnanthes longipes* | - | girdle and side view |
| | 4. | *Mastogloia pumula* | - | valve view |
| | 5. | *Mastogloia braunii* | - | valve view |
| | 6. | *Mastogloia exigua* | - | valve view |
| | 7. | *Mastogloia lanceolata* | - | valve view |
| | 8. | *Mastogloia dolosa* | - | valve view |
| | 9. | *Mastogloia exili* | - | valve view |
| | 10. | *Navicula permagna* | - | valve view |
| | 11. | *Navicula forcipata* | - | valve view |
| | 12. | *Navicula lyra* | - | valve view |
| | 13. | *Navicula gracilis* | - | valve view |
| | 14. | *Navicula gracilis* var. *schizonema* | - | valve view shows division |
| | 15. | *Navicula hasta* | - | valve view |
| | 16. | *Navicula pygmoea* | - | valve view |
| | 17. | *Navicula bicapitata* | - | valve view |
| | 18. | *Navicula granulata* | - | valve view |
| | 19. | *Navicula moniligera* | - | valve view |
| | 20. | *Navicula notabilis* | - | valve view |
| | 21. | *Navicula plicata* | - | valve view |
| | 22. | *Navicula hennedyel* var. *neopolitana* | - | valve view |
| | 23. | *Navicula hennedyei* var,. *nebulosa* | - | valve view |
| | 24. | *Dictyoneis marginata* | - | valve view |
| | 25. | *Caloneis liber* | - | valve view |
| | 26. | *Diploneis dydima* | - | valve view |
| | 27. | *Diploneis subovalis* | - | valve view |
| | 28. | *Diploneis splendida* | - | valve view |
| | 29. | *Diploneis smithii* | - | valve view |
| | 30. | *Diploneis elliptica* | - | valve view |
| | 31. | *Diploneis chersonensis* | - | valve view |
| | 32. | *Anomoeneis sculpta* | - | valve view |
| | 33. | *Trachyneis aspera* | - | valve view |
| | 34. | *Trachyneis antillarum* | - | valve view |
| | 35. | *Amphiphora gigantea* var. *sulcata* | - | valve view |
| | 36. | *Pleurosigma formosum* | - | valve view |
| | 37. | *Gyrosigma scalprodies* var. *eximia* | - | valve view |
| | 38. | *Gyrosigma balticum* | - | valve view |
| | 39. | *Amphora ovalis* | - | valve view |
| | 40. | *Eunotia monodon* | - | valve view |
| | 41. | *Eunotia diodon* | - | valve view |
| | 42. | *Epithemia turgida* | - | valve view |
| | 43. | *Encyonema prostratum* | - | valve view |
| | 44. | *Epithemia musculus* | - | valve view |
| | 45. | *Amphora laevissima* | - | girdle view |

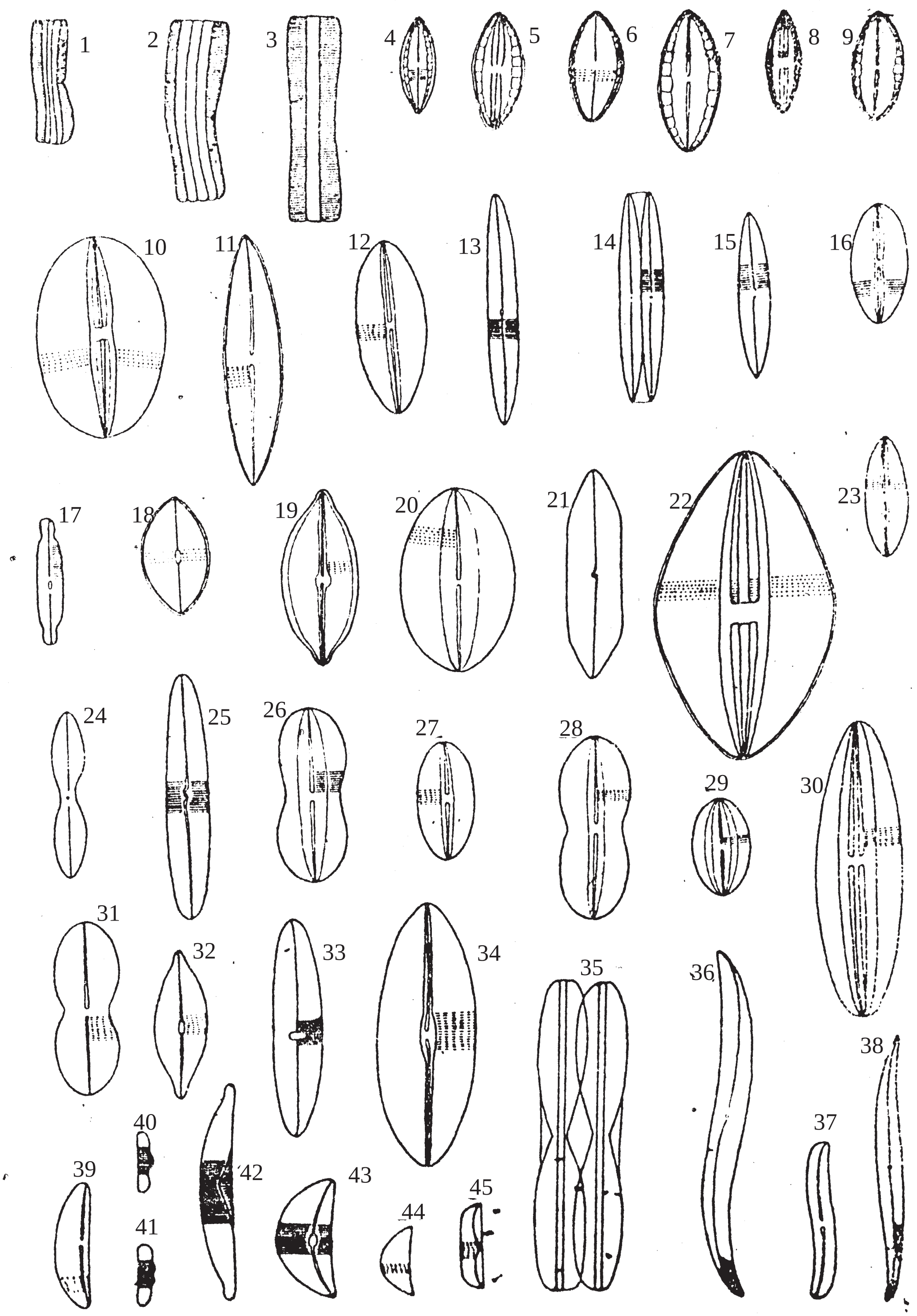
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Fig.II

| | | | |
|---|---|---|---|
| Fig. III 1. | *Amphora lineolata* | - | girdle view |
| 2. | *Amphora decussata* | - | girdle view |
| 3. | *Amphora ovalis* | - | girdle view |
| 4. | *Amphora ostrearia* | - | girdle view |
| 5. | *Amphora proteus* | - | girdle view |
| 6. | *Tropidoneis lepidoptera* | - | girdle view |
| 7. | *Tropidoneis antarctica* var. *polyplasta* | - | girdle view |
| 8. | *Amphora laevis* | - | valve view |
| 9. | *Tropidoneis semistriata* | - | valve view |
| 10. | *Cymbella cystula* | - | valve view |
| 11. | *Cymbella marina* | - | valve view |
| 12. | *Nitzschia panduriformis* | - | valve view |
| 13. | *Nitzschia sigma* | - | middle portion of the valve |
| 14. | *Nitzschia acuminata* | - | valve view |
| 15-16. | *Nitzschia sigma* var. *indica* | - | entire cell and middle portion |
| 17. | *Nitzschia obtusa* | - | valve view |
| 18. | *Nitzschia longissima* | - | valve view |
| 19-21. | *Bacillaria paradoxa* | - | 19, 21 two cells in girdle view and 20 shows the colony |
| 22-24. | *Hantzschia amphioxys* var. | - | valve view |
| 25. | *Surirella neumeyeri* | - | valve view |
| 26. | *Surirella fastuosa* | - | valve view |
| 27. | *Surirella fluminensis* | - | valve view |
| 28. | *Surirella eximia* | - | valve view |
| 29. | *Campylodiscus hodgsoni* | - | valve view |
| 30. | *Campylodiscus biangulatus* | - | valve view |

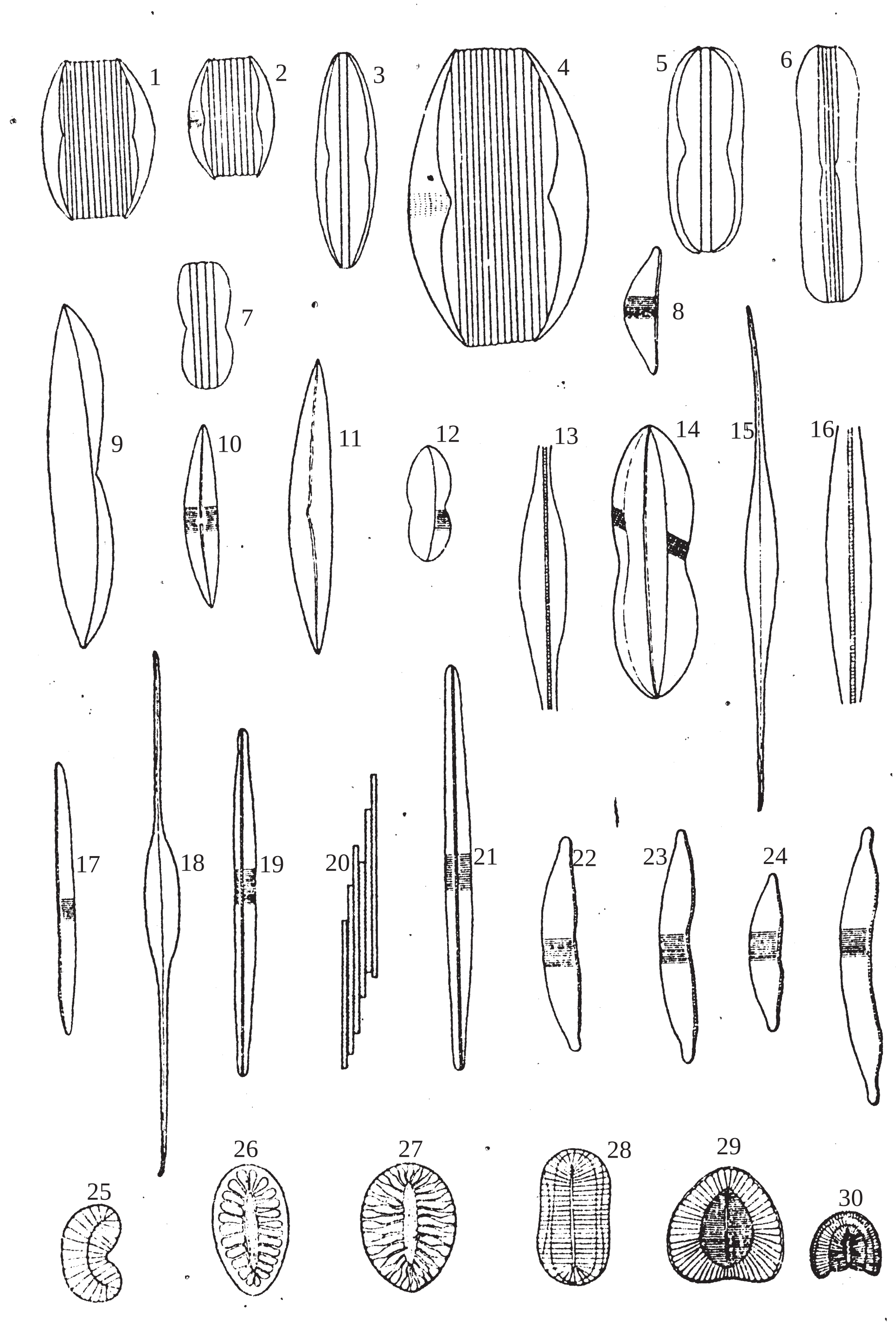
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Fig.III

Fig. IV 1. *Scenedesmus* sp.
2. *Oocystis* sp.
3. *Tetrahedron* sp.
4. *Chlorella* sp.
5. *Ulothrix* sp.
6. *Oedogonium* sp.
7. *Cladophora* sp.
8. *Chara* sp.
9. *Spirulina* sp.
10. *Anabaena* sp.
11. *Nostoc* sp.
12. *Oscillatoria* sp.
13. *Ulva reticulata*
14. *Enteromorpha* sp.
15. *Chaetomorpha* sp.
16. *Lyngbya* sp.

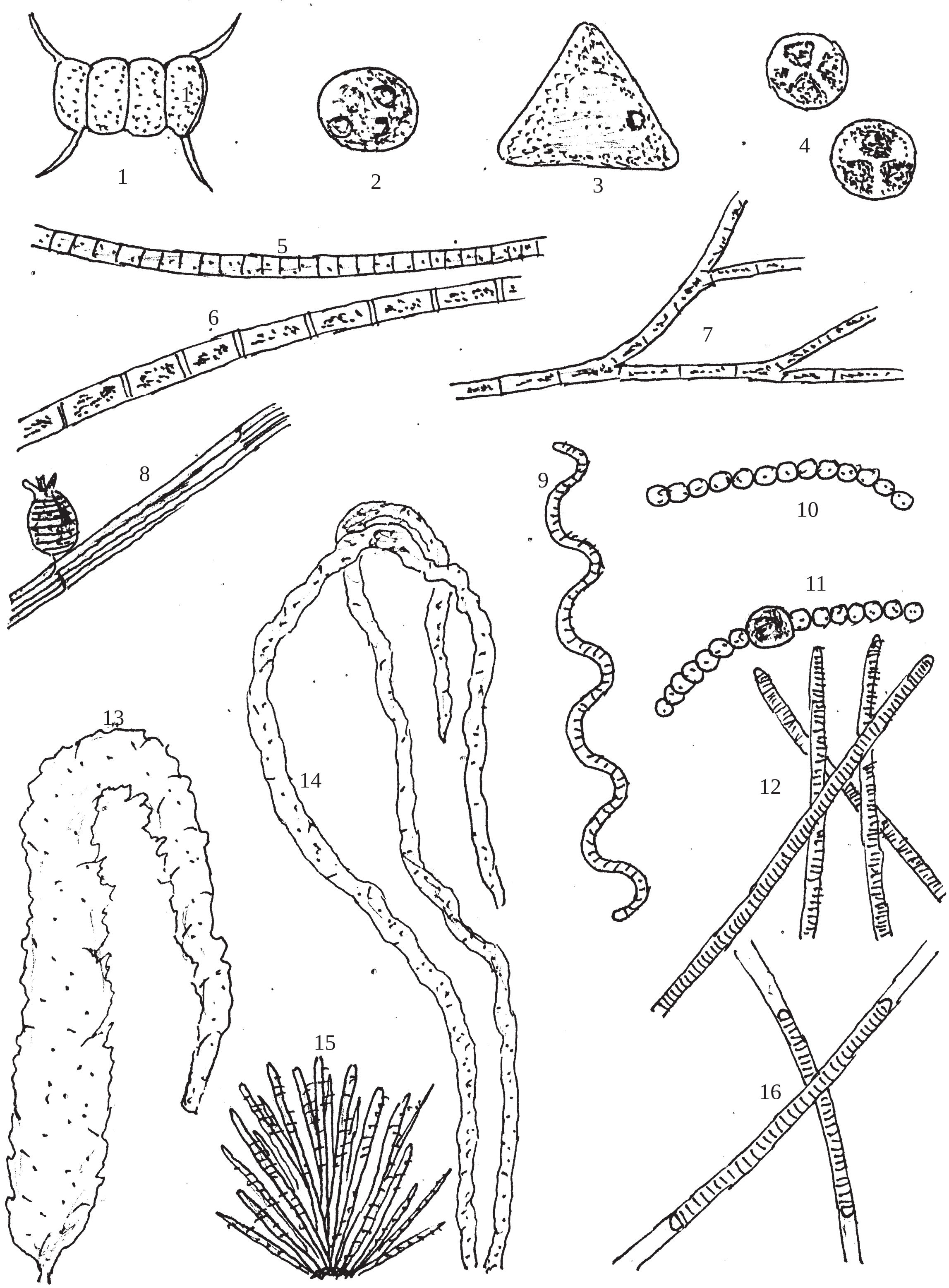
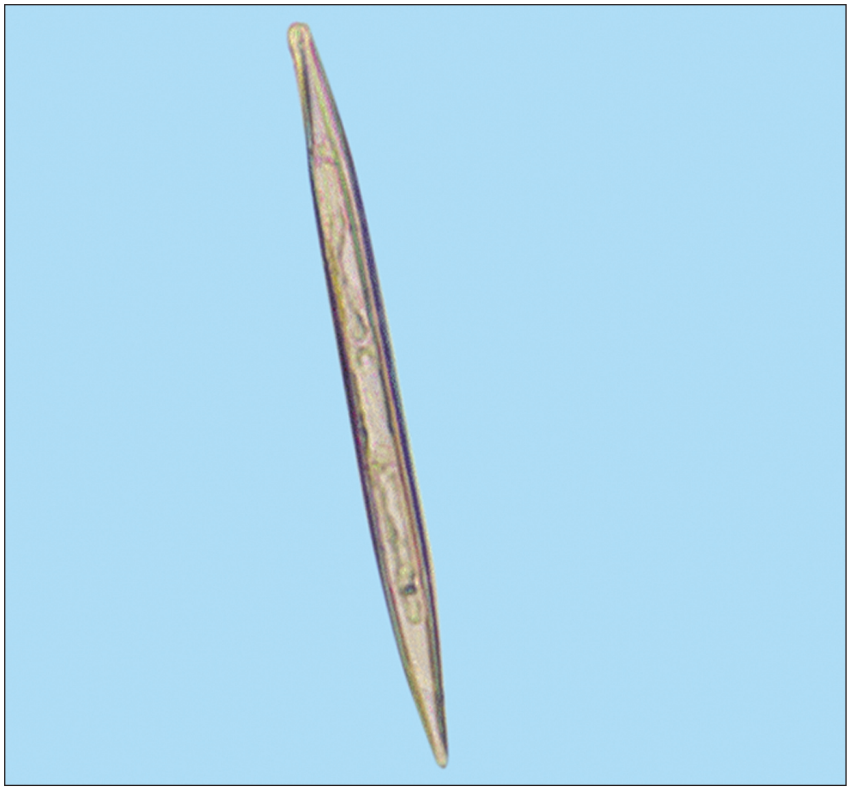



Fig.IV

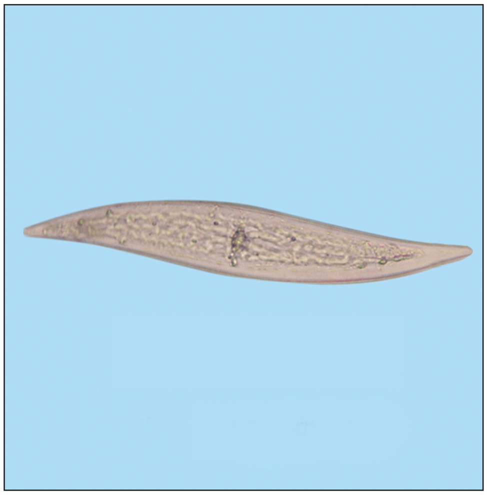
# Very common species of micro algae in the mangroves



*Bacillaria paradoxa*

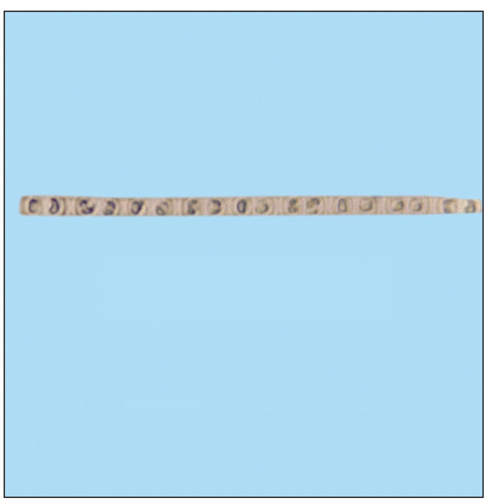
*Surirella splendida*

# Very common species of micro algae in the mangroves



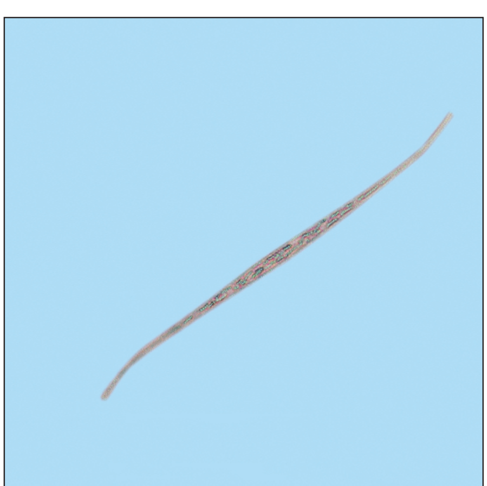
*Pleurosigma normannii*

*Surirella residense*

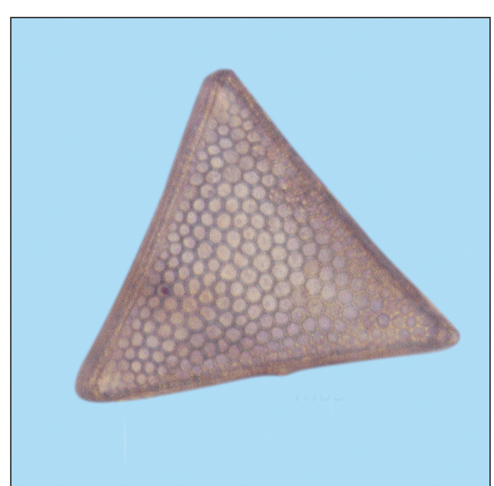


*Skeletonema costatum*

*Campylodiscus clypeuas*



*Nitzschia longissima*



*Triceratium favus*

# Zooplankton Fauna

T. S. Naomi, Ansy Mathew, George J. P., Sunirmal Giri and M. Kaliamoorthy

The zooplankton population consists of minute animals living freely in water with limited powers of locomotion and is more or less drifted passively by water currents. Almost every major group of animals, either as adults, larvae or as both has its representatives in planktonic existence. Many of the commercially important prawns, mussels, other shellfishes and finfishes start their life as plankters. The communities of zooplankton form the vital intermediary link in the food chain of the sea both as consumers of the primary producers and as contributors to the higher trophic level. Many species are proven indicators of pollution, water mass, cold, warm, surface or deep waters, upwelling characteristics and of the coastal or estuarine environment depending on the time of their occurrence and the ambient ecological parameters. Many are the holoplankters spending their entire life-cycle as plankters while some others like the eggs and larval stages of fishes, polymorphic forms such as hydroid medusae, occasional visitors like the young mussels, post-metamorphic juveniles in accidental pelagic state due to stirring up of the bottom or crustaceans simply swimming for a while in the shallow water over the intertidal zone when the tide floods, constitute the meroplankton of temporary pelagic phase. Thus the zooplanktons in general are multispecific in occurrence in relation to the water movement, ecological characters, depth, season and the prevailing conditions of the environment.

The zooplankton component of the mangrove fauna has not yet been studied in detail barring a few occasional reports. Several species are known to have life-history characteristics that are finely tuned to the unique ecosystem. The rich biotic environment and the high detritus content tend to make the coastal mangroves of the Indian subcontinent highly productive life sustaining systems. The flora and the vertebrate fauna of the mangroves received much attention in the past compared to the micro and macro fauna which are poorly understood even when the environment happens to be the known breeding ground for a variety of organisms. Three distinct types of organisms are observed here namely the exclusive mangrove residents; the marine species and fresh water species the last two are frequent visitors to the environment. One specific community may overlap with the other habitat community freely and frequently as and when the need arises.

The scarcity of specific information on the identity of the species of zooplankton fauna of the mangroves is a serious drawback. Adequate diagrams of certain common planktonic as well as non-planktonic animals followed by simple descriptions taken from published accounts are given wherever possible in the following pages. The uniqueness of the system and its varied inhabitants necessitate such a bold step so as to include the permanent and the temporary residents who have every chance to turn up at one time or the other in the planktonic collections due to tidal effects or any other disturbance which might come in their way of life.

## Method of Collection

Scoop-net bucket method is effectively used in surf/mangrove/swamps for the collection of zooplankton. The principle is to filter a known quantity of water (minimum 1 $m^3$ of water which is equivalent to 100 buckets of water drawn with a bucket of 10 litre capacity) through a scoop net (Mathew, 1998). The scoop net has a ring of 30 cm diameter made of a 12 mm aluminium rod. The ring is made in such a way that the two ends of the rod extend as a handle for holding the net. A net cone of 75 cm length tapering towards the cod end is attached to the ring. A plankton collection bucket is also fixed to the code end of the net with a window of the same net material. Appropriate lengths of 12.5 cm width of khaki cloth material are needed to attach the net cone to the net ring and the plankton collection bucket to the code end. Complete filtration of water is possible through the net and even bolting silk of smaller mesh sizes can be used as the net fabric to ensure the capture of tiny larval forms. For collecting a sample two persons go walking to the station and while one is holding the net slightly above the surface of water, the other person takes a 10-litre bucket full of water and pour it into the scoop net. The taking and pouring of water should be made as fast as possible to prevent the possibility of any plankton escaping the capture. The agitation caused in the water column will confuse the animals and in the process of haphazard movements the chances of escaping are brought to the minimum during the collection. The samples should be collected as early as possible in the morning hours.

**Preservation**

The net is washed after each collection by jet action of seawater to the outer sides of the net and thus the plankton sticking to the sides of the net is brought down to the collecting bucket. When the excess water is drained off the net through the window of the plankton collection bucket it is removed from the net and the plankton in sea water is poured into a wide mouthed polythene bottle of 500 ml capacity up to 375 ml. Commercial (40 %) formaldehyde solution is added in such a way so as to make the preservation 5 % strong. (50 ml commercial formalin and 25 ml sodium borate as buffer to 1000 ml plankton in seawater). One label on good quality paper is made in pencil or Indian ink showing the details such as the station number or name, date, time, type of collection and depth of the station and placed above the inner lid of the bottle below the screw cap. Important details such as the station number, date and type of collection are also written with a permanent marker pen on the outside of the bottle directly.

**Volume of Water Filtered**

Whenever there was some difficulty in filtering 1 $m^3$ of water the net was dragged above the bottom sediments without disturbing the mud for a known length of 100 m. The calculation is then based on the length of tow and the mouth area of the net ($\pi r^2 h$). Clogging of the meshes might introduce an error into this calculation. A flow meter of digital type, Hydrobios is tied to the mouth of the net to know the volume of water filtered by the net. It is a small device with a propeller at one end and a small window on one side where the revolutions of the propeller are indicated in numbers. The number of revolutions made by the flow meter is used to calculate the quantity of water filtered by the net in which it is used. The flow meter is calibrated at frequent intervals. The net fitted with the flow meter is lowered vertically to a known depth by releasing a known length of wire rope and hauled up at the rate of 1 m per second for the purpose of calibration. The number of revolutions made by the flow meter during the haul is noted. The net can also be used in a horizontal haul to record the number of revolutions made by the flow meter for a known distance. The volume of the water column through which the net travelled is then calculated using the formula $\pi r^2 h$ where r is the radius of the mouth ring and h is the known depth or the horizontal distance. By using the volume of water column and the number of revolutions made by the flow meter for filtering one cubic meter of water, the volume of water that can be filtered in one revolution is found out. This is the calibration factor that is used to multiply the number of revolutions made at each haul for a particular station to calculate the volume of water filtered by the net.

### Volumetric Analysis

The wet displacement method is used for the determination of the plankton volume. The volume determiner is a transparent cylindrical plastic apparatus of 100 ml capacity with both ends open. One end is fixed with a piece of netting of the same mesh size used for the plankton net and it can be fixed watertight over its plastic base. On the other end is a removable lid of plastic with a side hole. From the center of the lid hangs a metallic pointer needle which would reach up to the 50 ml mark made on the cylinder when the lid is fixed over the apparatus.

The preserved plankton is poured into the volume determiner. The water filters out and the interstitial water remaining in the plankton is removed by placing the cylinder over a blotting paper repeatedly till the water gets completely run out. The cylinder with the plankton is fixed watertight over its base. Adequate quantity of 5 % formaldehyde solution is slowly let out from a 50 ml burette inserted through the side hole of the lid of the apparatus without any air bubbles till the water level just touches the pointer of the lid. The level of solution remaining in the burette is equivalent to the volume of plankton in the cylinder. The volume of plankton per 100 $m^3$ of water filtered can be estimated after calculating the quantity of water filtered by the net during sampling.

### Zooplankton Sub-sampling

A minimum quantity of 5 ml of plankton as determined by the wet displacement volume method is analysed for groups and species to get adequate representation. If the total volume is more than 5 ml the sample is sub sampled using a device Folssom Splitter. It is used to divide a sample into two equal halves at a time.

### Sorting and Counting

The sub-sampled plankton is analysed fully either by sorting out or enumerating the constituents in a plankton counting chamber after identification under a stereoscopic binocular microscope. The sorted plankton groups are further analysed to the species level.

### Labelling and Packing

The sorted groups or species are packed in small glass vials of appropriate sizes decided by the quantity of material to be packed. Preservation liquid is filled to the brim of the vial. A label indicating the sampling details and the name of the group or species is inserted into the vial and then plugged tightly with cotton without any air bubbles. All the vials pertaining to a group or species from the stations of a region are packed in a wide mouthed plastic jar after placing sufficient quantity of cotton at the bottom of the jar to prevent accidental breakage of the vials. The remaining space in the jar is also packed with cotton so that the vials will not be broken during transportation. Preservation liquid is poured to the brim of the jar. One label with full details is placed above the inner lid and another is pasted on the outside of the jar.

### Plankton Data Base

A register is kept ready for entering the zooplankton data after analysing the samples incorporating details of area and collection method, species identification, enumeration and volume quantified per 100 $m^3$. Thus the database of zooplankton collections from a particular region or ecosystem is maintained for further treatment of the data.

## FAUNISTIC COMPOSITION OF THE MANGROVE ECOSYSTEM

Kingdom **ANIMALIA**

Phylum **ARTHROPODA**

| | |
|---|---|
| Subphylum | **CRUSTACEA** Brunnich, 1772 |
| Class | **MAXILLOPODA** Dahl, 1956 |
| Subclass | **COPEPODA** Milne-Edwards, 1840 |
| Infraclass | **NEOCOPEPODA** Huys & Boxshall, 1991 |
| Superorder | **GYMNOPLEA** Giesbrecht, 1882 |
| Order | **CALANOIDA** Sars, 1903 |

The recorded copepod crustaceans from the mangrove ecosystem are regrouped as per the updated classification of the recent crustacea by Martin and Davis (2001). Accordingly, the infraclass Neocopepoda is divided into two superorders Gymnoplea Giesbrecht, 1882 and Podoplea Giesbrecht, 1882. The order Calanoida Sars, 1903 is thus grouped under the superorder Gymnoplea while the other three orders Cyclopoida Burmeister, 1834, Harpacticoida Sars, 1903 and Poecilostomatoida Thorell, 1859 are kept under the superorder Podoplea.

Copepod crustaceans in general are small in size and the body is divisible into head, thorax bearing biramous (paired) appendages and abdomen devoid of any appendages. The head and thorax merging smoothly to form a fore-body, a shell fold or carapace is absent, a simple median or nauplius eye with three ocelli although extra eyes occur in some species. A copepod is usually regarded as being built of a head comprising six segments-cephalosome, a thorax of six segments-metasome and an urosome or abdomen of four segments plus a telson or anal segment which bears the caudal rami or furca. Frequently, the first segment of the metasome is fused with the cephalosome, and /or the fourth and fifth segments of the metasome are fused. Thus, the metasome in some species may seem to have as few as three segments. The degree of fusion between segments is variable between the main suborders and the genital aperture is indistinguishably fused with the first abdominal segment in the female, while in the male these two segments remain separate. The cephalosome and metasome together are known as the prosome. There is no agreed system for the enumeration of copepod segments or for the names of appendages that they bear. The names of the appendages generally followed are for the head - antennules, antenna, mandible, maxilla and 1st maxilliped and for the thorax - 2nd maxilliped, 1st swimming leg, 2nd swimming leg, 3rd swimming leg, 4th swimming leg and 5th swimming leg. Diagrammatic illustrations on the external morphology and appendages of the copepods taken from Kasturirangan (1963), Newell and Newell (1977) and Mauchline (1998) are given in Figs.1; 2.a, 2.b, 2.c; 3, 4.1 & 4.2. The external appearance of a copepod often provides an important clue in identifying the various genera.

Among copepods, calanoids are the most numerous; primarily pelagic, 75% marine and the rest 25% live in fresh water. Some marine species are benthopelagic or commensal. The morphological characters of calanoids, cyclopoids and harpacticoids are shown in Fig.1; 2.a, 2.b & 2.c. The external features that distinguish the calanoids (Fig.1 & 2.a) from cyclopoids and harpacticoids are given below:

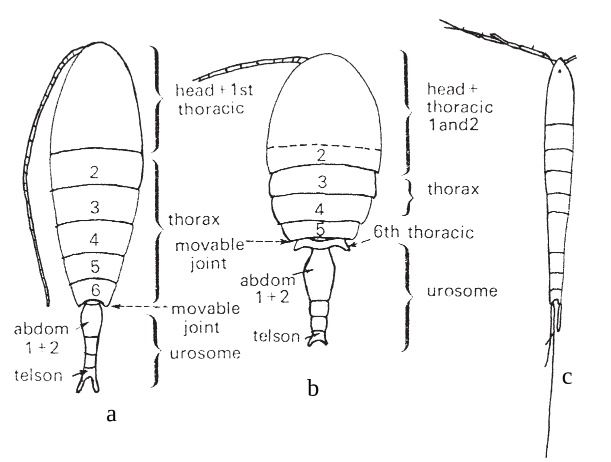



Fig. 1. Planktonic copepods-differences in the external morphology. (a) Female calanoid (b) Female cyclopoid (c) Female harpacticoid. (Newell & Newell, 1977)

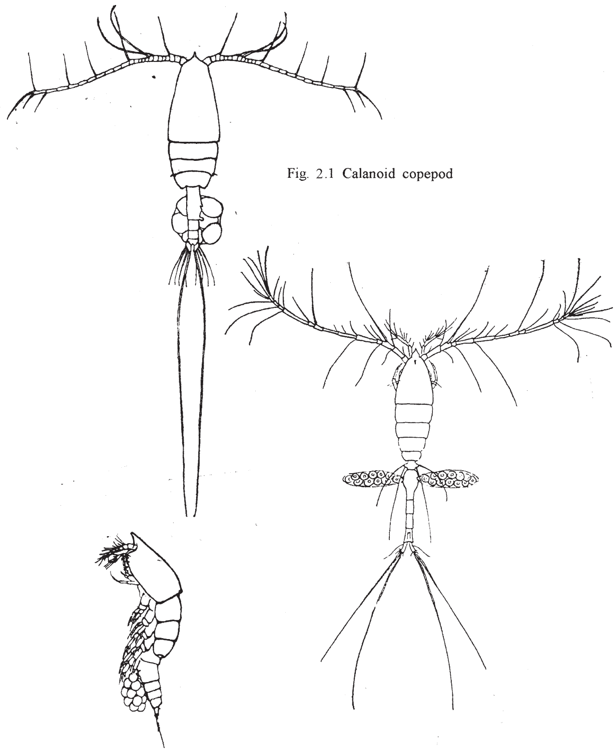



Fig. 2. External morphology of mature females (a) Female calanoid (b) Female cyclopoid (c) Female harpacticoid. (Kasturirangan, 1963)

- The antennules (1st antennae) are long and are composed of numerous segments or joints.
- The 2nd antennae are short.
- The body is not depressed and habits not ectoparasitic except in very rare cases.
- The metasome ends behind the segment of the 4th or 5th pair of legs.
- The eggs, except in a few genera, are carried by the female in a single cluster - not in paired egg sacs and always the eggs are shed freely into the water.
- The genital apertures (paired in the female and unpaired in the male) are borne on the first abdominal segment.
- The first antennae of the male, if geniculate, geniculate on one side only, commonly on the right side.
- The males of many species have one (either the left or the right) of the last pair of thoracic limbs modified as forceps in transferring the spermatophore to the female.

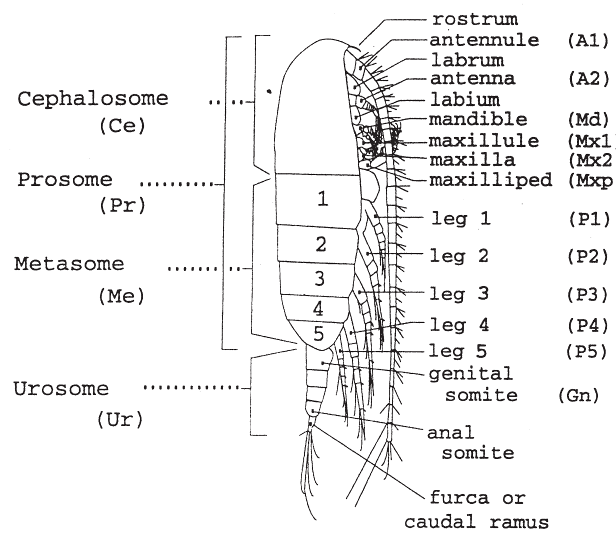



Fig. 3. Diagrammatic illustration of the external morphology and appendages of a female calanoid copepod (Mauchline, 1998)

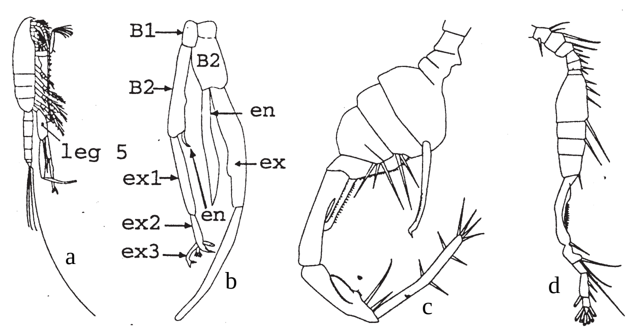



Fig. 4.1 Diagrammatic illustration of the external morphology and some appendages of a male calanoid copepod. (a) Male lateral view (b) Male 5th pair of legs (c) Male geniculate right antennule of *Pontella* species (d) Male geniculate right antennule of a *Candacia* species (Mauchline, 1998).

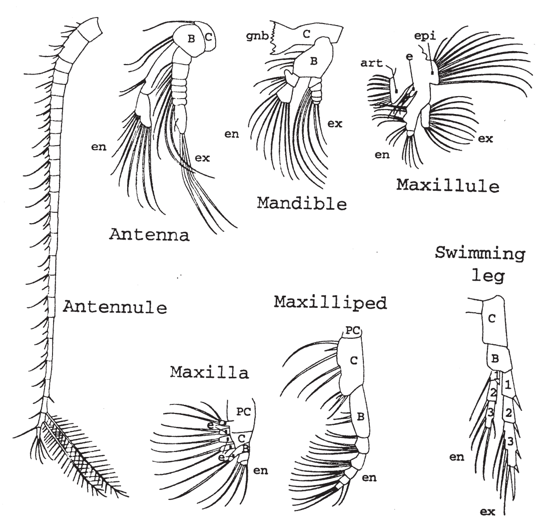



Fig. 4.2 Diagrammatic illustrations of the appendages of a calanoid copepod art-arthrite; B-basis; C-coxa; e-endite; en-endopod; epi-epipodite; ex-exopod; gnb-gnathobase; PC-praecoxa. (Mauchline, 1998).

Superorder **PODOPLEA** Giesbrecht, 1882

Order **CYCLOPOIDA** Burmeister, 1834

The cyclopoid copepods are divided between marine and fresh waters and can be pelagic, commensal or parasitic. The general characters (Figs.1 & 2.b) are:

- The body usually depressed with the metasome much wider than the urosome.
- The urosome consists of five segments in the female and six in the male plus a telson, but fused in some.
- The antennules (1st antennae) are short and have only a few joints.
- The egg sacs are paired in most species and carried laterally or subdorsally.
- The geniculation of the first antennae of the male is usual but not invariable.
- The basal segment of the 5th legs without an inner expansion.

Order **HARPACTICOIDA** Sars, 1903

The harpacticoids are primarily marine species, 10% living in fresh waters. The vast majority of harpacticoids are benthic, a few pelagic or commensal. Some are truly planktonic particularly in shallow seas with a sandy or muddy floor. The distinguishing features (Figs.1 & 2.c) are:

- The body usually cylindrical, the metasome passing into the urosome without any abrupt change in width.
- They are minute in size, majority less than 1 mm long.
- The egg sacs may be single or paired, usually unpaired and carried underneath.
- The antennules (1st antennae) are short, usually with less than six joints.
- The basal segment of the 5th legs usually showing an inner expansion.
- The males are distinguished from the females in all cases by the geniculation of the 1st antennae.

Order **POECILOSTOMATOIDA** Thorell, 1859

Three genera ***Corycaeus***, ***Oncaeus*** and ***Sapphirina***, which were recognized earlier under the order Cyclopoida, are exclusively marine and hence given a separate order Poecilostomatoida Thorell, 1859.

Order **CALANOIDA** Sars, 1903

Family **ACARTIIDAE** Sars, 1900

Genus ***Acartia***

Second antennae with two-jointed endopod in which the distal segment is almost as long as the proximal, posterior margin of the metasome drawn out into spines. **Females**: 5th legs always uniramous, slender and spine-like and urosome 3-segmented, 1st antennae alike on two sides. **Males**: urosome 5-segmented, 4th segment very short, 2nd largest of all, 1st with lateral genital aperture and 1st antenna on the right side is indistinctly geniculate. 5th legs uniramous.

**1.** ***Acartia spinicauda*** Giesbrecht **Female**: The spines of the metasome corners are smaller compared to ***A. erythraea*** and ***A. centrura***, terminal claw of 5th leg scarcely widened at base, straight, without notch and with serrations on distal half, length 1.0 to 1.3 mm; (Fig. 1.a, b & c).

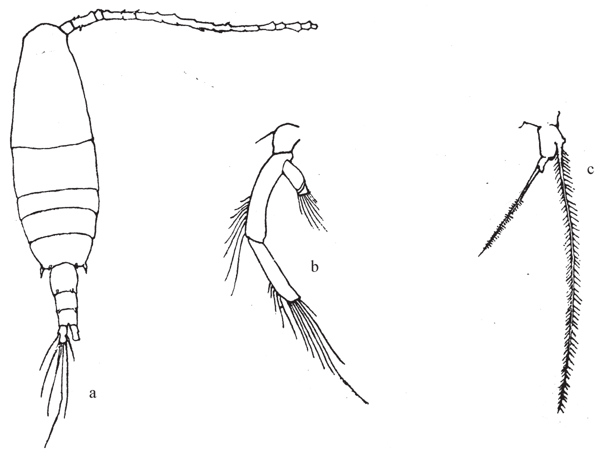



Fig. 1. *Acartia spinicauda* Giesbrecht (a) Female dorsal view. (b) Female 2nd antenna. (c) Female 5th leg. (Kasturirangan, 1963)

**Male**: The 2nd urosome segment with two pairs of spines, inner pair smaller than outer; spines on 3rd urosome segment are long and over-reach the very short 4th segment, length 1.0 to 1.2 mm; (Fig. 2.a & b).

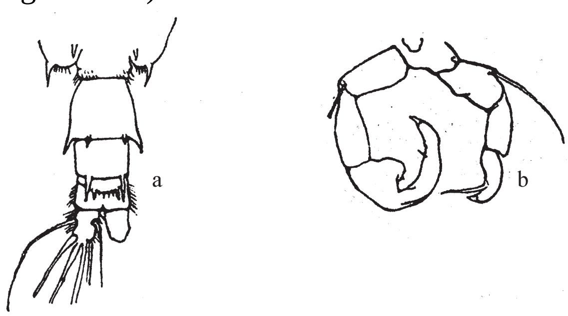



Fig. 2. *Acartia spinicauda* Giesbrecht (a) Male urosome dorsal view. (b) Male 5th pair of legs, anterior view. (Kasturirangan, 1963).

**2. *Acartia erythraea*** Giesbrecht **Female**: The 2nd urosome segment bears two small inconspicuous spines placed close together; terminal claw of 5th leg thickened a little at the base, curved, smooth, and without any notch, length 1.0 to 1.4 mm; (Fig.1.a & b).


Fig 1. *Acartia erythraea* Giesbrecht. (a) Female dorsal view. (b) Female 5 th leg. (Kasturirangan, 1963).

**Male**: The 2nd urosome segment wider than long, with two pairs of prominent spines, inner pair as large as the outer; length 1.0 to 1.3 mm; (Fig. 2.a & b).

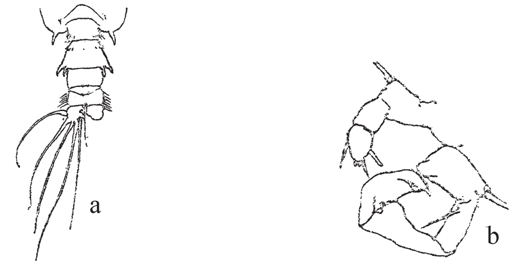



Fig. 2. *Acartia erythraea* Giesbrecht. (a) Male urosome. (b) Male 5th leg. (Kasturirangan, 1963).

**3. *Acartia centrura*** Giesbrecht **Female**: The 2nd urosome segment bears two spines that are comparable in size and position to the spines on the 1st urosome segment. The spines of the metasome corners are as large as in ***A. erythraea*;** terminal claw of 5th leg swollen at the base, smooth, straight and with a distinct notch; length 1.20 to 1.24 mm; (Fig.1.a & b).

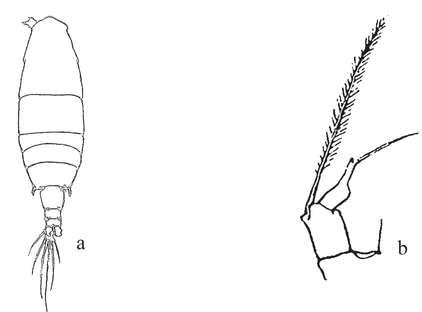



Fig. 1. *Acartia centrura* Giesbrecht. (a) Female dorsal view. (b) Female 5th leg. (Kasturirangan, 1963).

**Male**: The 2nd urosome segment with three pairs of spines, the two inner pairs quite small, the outer pair a little longer; spines on 3rd urosome segment do not fully overreach the 4th segment; length 1.02 mm; (Fig. 2.a & b).

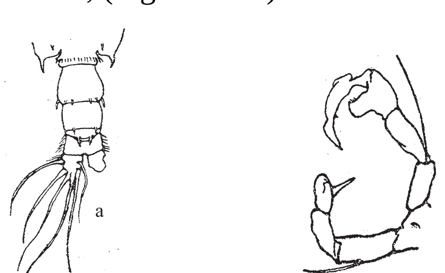



Fig. 2. *Acartia centrura* Giesbrecht. (a) Male urosome, dorsal view (b) Male 5th pair of legs anterior view. (Kasturirangan, 1963).

**4.** ***Acartia chilkaensis*** Sewell **Female**: Metasome posterior margin smooth or with minute spinules only; habitat estuarine and brackish water. 5th legs straight, with a notch as in ***A. centrura*** but set with short hairs on both margins; length 1.0 to 1.1 mm in both sexes; (Fig. 1.a, b & c).

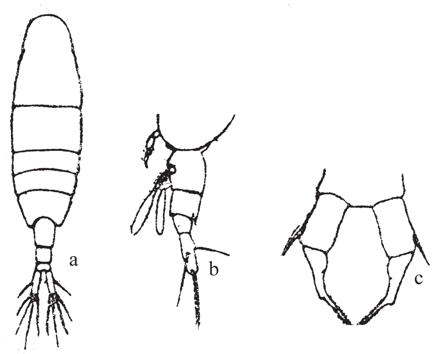



Fig. 1. *Acartia chilkaensis* Sewell. (a) Female, dorsal view. (b) -Female, urosome, lateral view. (c) Female, 5th pair of legs. (Kasturirangan, 1963).

**Male**: Same as in female. Length 1.0 to 1.1 mm; (Fig. 2.a & b).

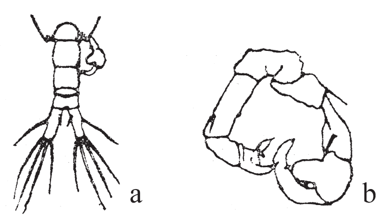



Fig. 2. *Acartia chilkaensis* Sewell. (a) Male, 5th pair of legs, posterior view. (b) Male, urosome and a part of metasome, dorsal view. (Kasturirangan, 1963).

**5.** ***Acartiella sewelli*** Steuer **Female**: Urosome 3-segmented, anal segment very short; right caudal ramus a little longer than the left, 5th legs biramous, length 1.38 to 1.57 mm; (Fig.1.a, b & c).

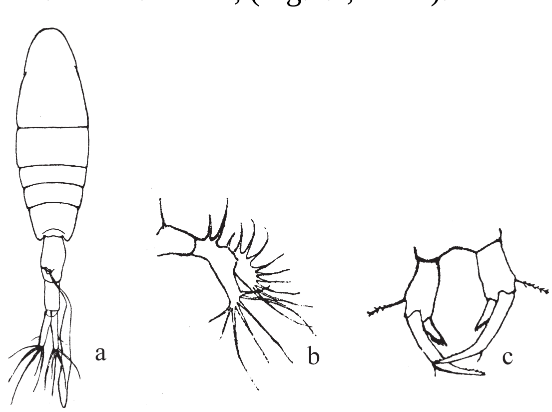



Fig. 1. *Acartiella sewelli* Steuer. (a) Female, dorsal view. (b) Female, 2nd antenna. (c) Female, 5th pair of legs. (Kasturirangan, 1963).

**Male**: Urosome 4-segmented, right caudal ramus longer than the left; this inequality is more pronounced in the male; right leg longer and with a short process arising from its basal segment; length 1.27 to 1.51 mm; (Fig. 2.a & b).

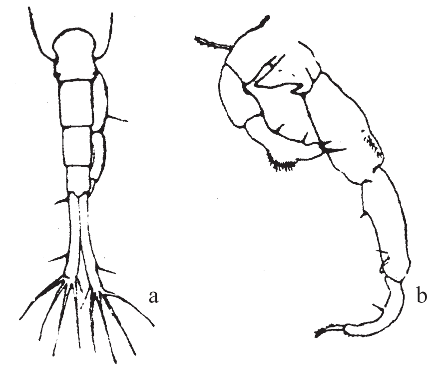



Fig. 2. *Acartiella sewelli* Steuer. (a) Male, urosome, dorsal view (b) Male, 5th pair of legs, posterior view. (Kasturirangan, 1963).

Family **CALANIDAE** Dana, 1846

Genus ***Canthocalanus***

Basipod of 1st legs with a hook and seta arrangement on the anterior face; inner margin of basipod 1 of 5th legs smooth in both sexes.

**1.** ***Canthocalanus pauper*** (Giesbrecht) **Female**: Urosome 4-segmented; exopodites of the 5th legs with plumose setae; length 1.7 mm; (Fig. 1. a, b & c).

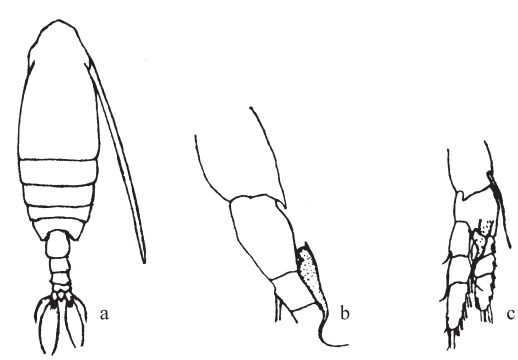



Fig. 1. *Canthocalanus pauper* (Giesbrccht). (a) Female, dorsal view. (b) Female, 1st leg, anterior face. (c) Female, 1st leg, lateral view. (Kasturirangan, 1963).

**Male**: Urosome 5-segmented; exopodites of the 5th legs without plumose setae; the left exopod often flexed outwards to assume a hammer-like form; left endopod with 2 terminal setae only; length 1.4 mm; (Fig. 2. a, b, c & d).

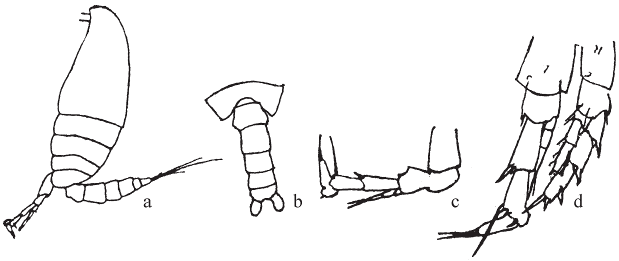



Fig. 2. *Canthocalanus pauper* (Giesbrecht). (a) Male, lateral view. (b) Male urosome. (c) Male, left 5th leg, in flexed position, (d) Male, 5th pair of legs, posterior view. (2.b&d Dakin and Colefax, 1940; Kasturirangan, 1963).

Family **CENTROPAGIDAE** Giesbrecht, 1893

Genus ***Centropages***

The endopodites of the 5th legs are 3-segmented and with plumose setae, constructed as swimming legs; the 2-segmented appearance of the endopods of legs 1 to 4 is secondary owing to the fusion of the proximal segment with the middle segment, partially in leg 4 and more completely in legs 3, 2 and 1.

**1. *Centropages furcatus*** (Dana) **Female**: Posterior margin of metasome provided with two smaller, more dorsally placed spines in addition to the two large ones; a tooth present on the anterior margin of segments 1, 2 and 5 of 1st antennae; eye, red in colour, in continuous movement in the living condition. Length of female 1.9 mm; (Fig.1. a & b).

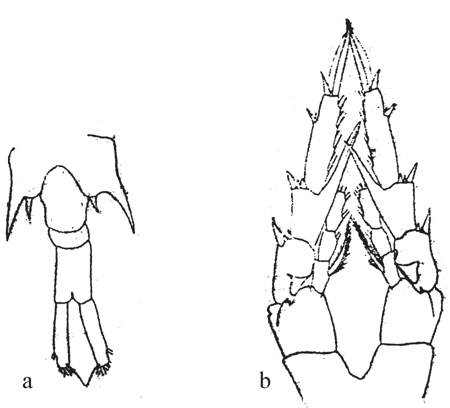



Fig. 1. *Centropages furcatus* (Dana). (a) Female urosome and part of metasome dorsal view. (b) Female, 5th pair of legs, posterior view. (Dakin and Colefax, 1940).

**Male**: Same as in female. Length of male 1.5 to 1.7 mm; (Fig. 2. a, b & c).

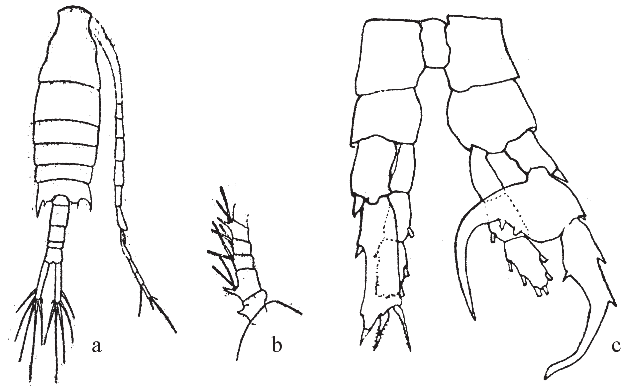



Fig. 2. *Centropages furcatus* (Dana). (a) Male dorsal view. (b) Male proximal five segments of 1st Antenna. (c) Male 5th pair of legs, posterior view. (2.a&b Dakin and Colefax, 1940; Kasturirangan, 1963).

2. ***Centropages orsinii*** Giesbrecht **Female**: Urosome 3-segmented; length 1.7 mm; (Fig. 1. a & b).

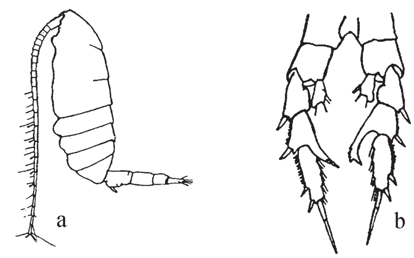



Fig. 1. *Centropages orsinii* Giesbrecht. (a) Female, lateral view. (b) Female, 5th pair of legs, posterior view. (Kasturirangan, 1963).

**Male**: Urosome 4-segmented; length 1.3 to 1.5 mm; (Fig. 2. a & b).

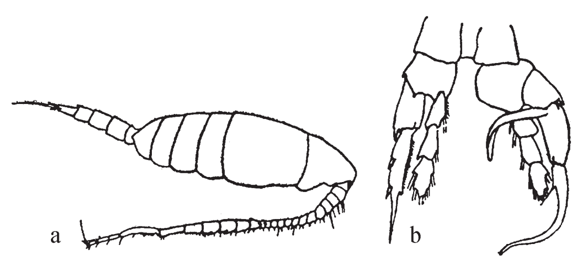



Fig. 2. *Centropages orsinii* Giesbrecht. (a) Male, lateral view. (b) Male, 5th pair of legs, posterior face. (Kasturirangan, 1963).

Family **DIAPTOMIDAE** Baird, 1850

Exclusively a freshwater family consisting of about 30 genera in two subfamilies, many are common and widely distributed in the tropical waters. Most of the genera belong to the subfamily Diaptominae.

Genus ***Diaptomus***

***1. Diaptomus*** species. **Female**: Body slender, endopod 3-segmented in the 2nd, 3rd and 4th thoracic legs except the 1st which is 2-segmented; 5th leg biramous, rami 1 to 2-segmented with or without two apical setae; (Fig. 1. a).

**Male**: 5th legs asymmetrical, endopod rudimentary, right leg ending in a single claw; furcal processes short; (Fig. 2. a).

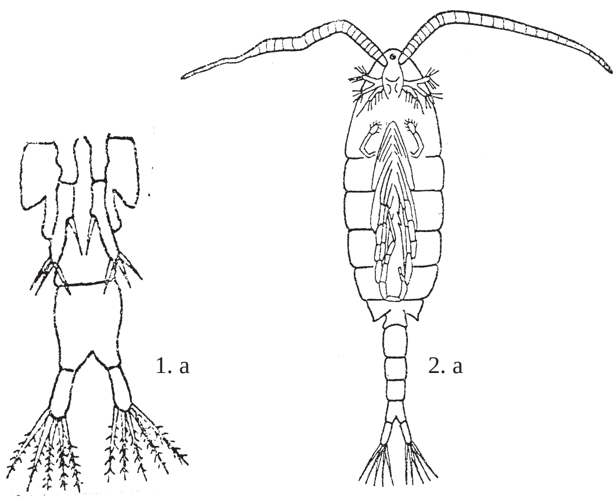



Fig. 1 a. *Diaptomus* sp. Female urosome and part of metasome. 2 a. *Diaptomus* sp. Male ventral view. (Sehgal, 1983).

Family **PARACALANIDAE** Giesbrecht, 1893

Genus ***Paracalanus***

Terminal segment of the exopodites of legs 2, 3 and 4 is separated into a proximal and a distal portion by the outer marginal spine such that the proximal portion is at least twice as long as the distal portion; 2nd antenna of the female with the 7-segmented exopodite as long as the 2-segmented endopodite; 5th legs present in female.

**1. *Paracalanus parvus*** (Claus) **Female**: First antennae not generally reaching beyond the caudal rami, surface of basipod 1 of legs 1 to 4 beset by hairs and bristles; urosome 4-segmented; 5th legs symmetrical, 2-segmented, genital opening oval, broader than long. Length 0.8 to 1.00 mm; (Fig.1. a, b, c & d).

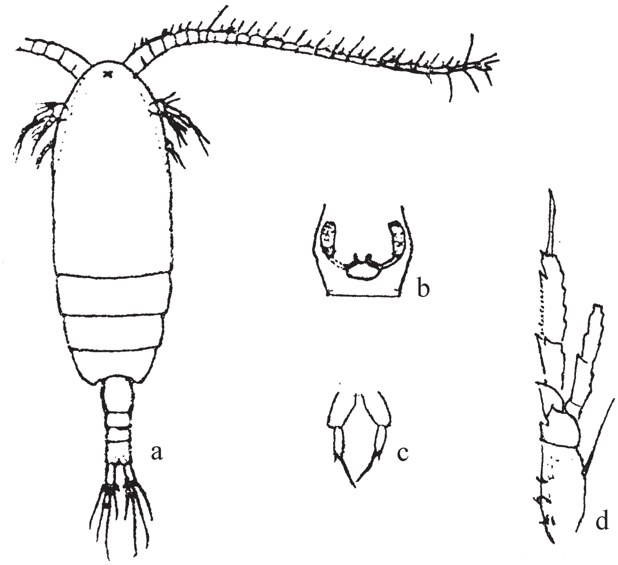



Fig. 1. *Paracalanus parvus* (Claus) (a) Female dorsal view. (b) Female genital segment, ventral view. (c) Female 5th pair of legs. (d) Female 4th leg, to show hairs and spines on the 1st basipodite segment. (Kasturirangan, 1963).

**Male**: First antennae not generally reaching beyond the caudal rami, surface of basipod 1 of legs 1 to 4 beset by hairs and bristles; urosome 5-segmented; 5th legs asymmetrical, 2-segmented on the right and 5-segmented on the left, left foot much longer; bubble like eminence on cephalosome indistinct or absent in profile view. Length 0.9 to 1.00 mm; (Fig.2. a, b & c).

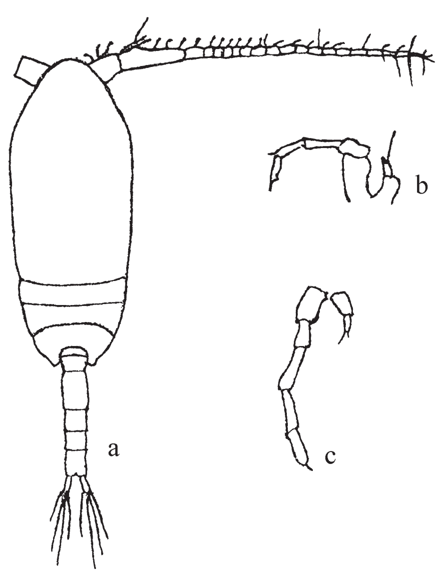



Fig. 2. *Paracalanus parvus* (Claus) (a) Male dorsal view. (b & c) Male 5th pair of legs two views. (Kasturirangan, 1963).

***2. Paracalanus aculeatus*** (Giesbrecht) **Female**: First antennae reaching beyond the caudal rami; surface of basipod 1 of legs 1 to 4 naked except for one plumose seta though hairs and bristles occur on the segments of the exopod and endopod. Urosome 4-segmented; 5th legs symmetrical, 2-segmented, genital opening circular. Length 1.25 mm; (Fig.1. a, b & c).

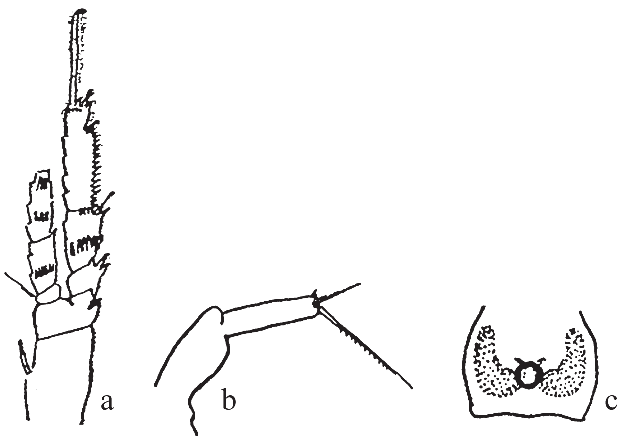



Fig. 1. *Paracalanus aculeatus Giesbrecht,* (a) Female 4th leg, to show absence of hairs and spines on the 1st basipodite segment. (b) Female 5th leg. (c) Female genital segment, ventral view. (Kasturirangan, 1963).

**Male**: First antennae reaching beyond the caudal rami; surface of basipod 1 of legs 1 to 4 naked except for one plumose seta though hairs and bristles occur on the segments of the exopod and endopod urosome 5-segmented; 5th legs asymmetrical, short and 3-segmented on the right side, long and 5-segmented on the left side, bubble like eminence on cephalosome quite distinct in profile view. Length 1.20 mm; (Fig.2. a & b).

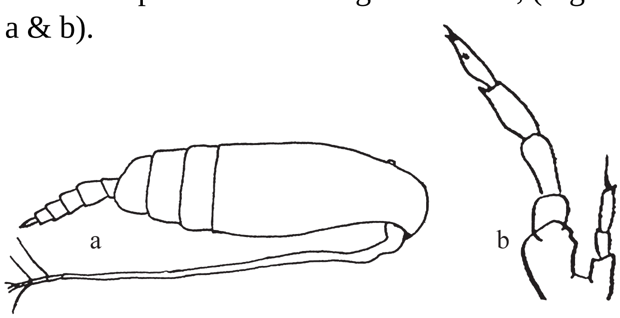



Fig. 2. *Paracalanus aculeatus* Giesbrecht (a) Male lateral view. (b) Male, 5th pair of legs. (Kasturirangan, 1963).

Genus ***Acrocalanus***

Terminal segment of the exopodites of legs 2, 3 and 4 is separated into a proximal and a distal portion by the outer marginal spine such that the proximal portion is less than twice as long as the distal portion; 2nd antenna of the female with the 7-segmented exopodite shorter than the 2-segmented endopodite; 5th legs absent in female.

**1. *Acrocalanus gibber*** Giesbrecht **Female**: First antenna does not reach beyond caudal rami; cephalosome in lateral view with a humped outline; body compact, urosome 4 - segmented; 5th legs absent. Length 0.93 to 1.00 mm; (Fig.1. a & b).

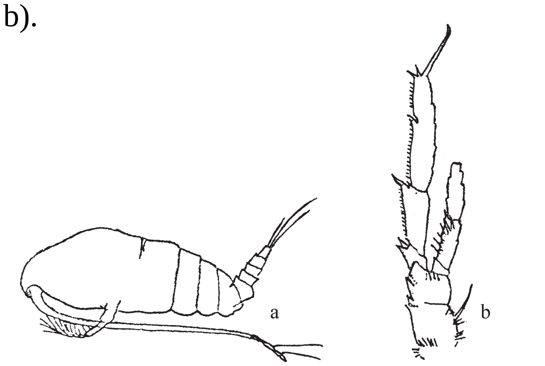



Fig. 1. *Acrocalanus gibber* Giesbrecht (a) Female lateral view. (b) Female 4th leg. (Kasturirangan, 1963).

**Male**: Urosome 5-segmented; 5th leg 4-segmented present on the left side only.

**2. *Acrocalanus longicornis*** Giesbrecht **Female**: First antenna reaches beyond caudal rami; cephalosome in lateral view not humped outline; body more elongated, urosome 4 - segmented; 5th legs absent. Length 1.14 to 1.20 mm; (Fig.1. a & b).

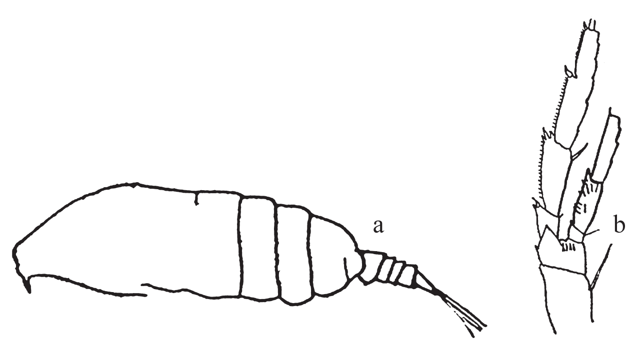



Fig. 1. *Acrocalanus longicornis* Giesbrecht (a) Female lateral view. (b) Female 4th leg. (Kasturirangan, 1963).

**Male**: Urosome 5-segmented; 5th leg 4-segmented present on the left side only.

Family **PONTELLIDAE** Dana, 1852

Genus ***Labidocera***

Body not usually pellucid, anterior lip not greatly enlarged; 5th legs not very slender or spine like; endopod of 2nd antenna 2-segmented with distal segment shorter than proximal. One pair of cuticular eye-lenses present dorsally on the cephalosome. Females only: urosome 3-segmented; 1st antennae symmetrical. Males only: urosome 5-segmented, 1st antenna geniculate on the right side.

**1.** ***Labidocera minuta*** Giesbrecht **Female**: Posterior margins of metasome rounded, with a very small projection present only on the right side, not visible in dorsal view; length 2.1 mm; (Fig. 1.a, b, c & d).

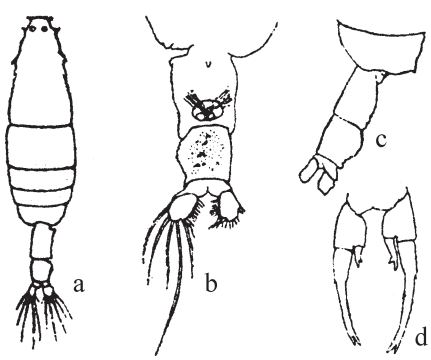



Fig. 1. *Labidocera minuta* Giesbrecht (a) Female dorsal view. (b) Female part of metasome and urosome ventral view. (c) Female part of metasome and urosome dorosolateral view. (d) Female 5th pair of legs. (Kasturirangan, 1963).

**Male**: Corners of metasome drawn out into prominent spines, the spine on the right side longer and somewhat spatulate; length 1.54 to 1.75 mm; (Fig. 2.a & b).

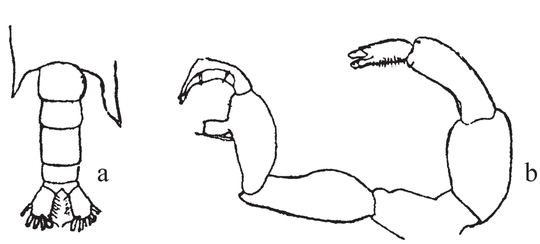



Fig. 1. *Labidocera minuta* Giesbrecht (a) Male part of metasome and urosome dorsal view. (b) Male 5th pair of legs. (Kasturirangan, 1963)

***3. Labidocera pectinata*** Thompson & Scott **Female**: Corners of metasome drawn out into curved points that can be clearly seen in lateral view, length 2.1 mm; (Fig.1. a, b, c & d) and (Fig.1.2. a, b & c).

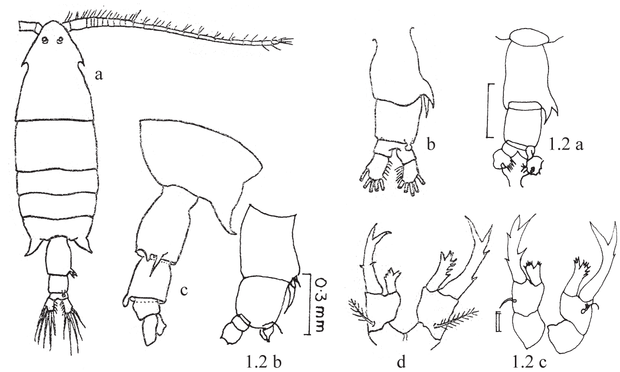



Fig. 1. *Labidocera pectinata* Thompson and Scott (a) Female dorsal view. (b) Female urosome dorsal view. (c) Female part of metasome and urosome view from the right. (d) Female 5th pair of legs, posterior view.

Fig. 1.2. *Labidocera pectinata* Thompson and Scott (a) Female urosome. (b) Urosome female (variant). (c) Female 5th pair of legs. (1.2a, 1,2b, 1.2c Silas and Pillai, 1973; Kasturirangan, 1963).

**Male**: Corners of metasome drawn out into prominent spines, the spine on the right side bifid, length 1.7 mm; (Fig.2. a, b & c) and (Fig. 2.1. a, b & c).

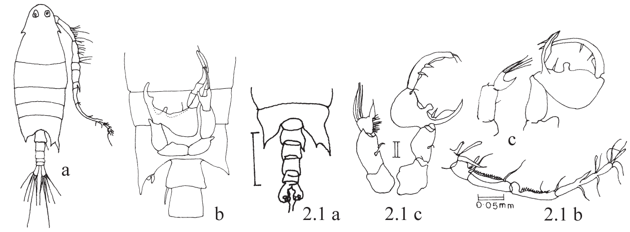



Fig. 2. *Labidocera pectinata* Thompson and Scott (a) Male dorsal view. (b) Male ventral view to show 5th pair of legs in position. (c) Male 5th pair of legs.

Fig. 2.1. *Labidocera pectinata* Thompson and Scott (a) Male urosome dorsal view. (b) Male 1st antenna. (c) Male 5th pair of legs. (2.1a, 2.1b, 2.1c Silas and Pillai, 1973; Kasturirangan, 1963).

**3.** ***Labidocera pavo*** Giesbrecht **Female**: Corners of metasome end in points but not drawn out; urosome condensed, very short, with a peg-like projection on the right side, length 1.9 mm; (Fig. 1. a, b, c & d).

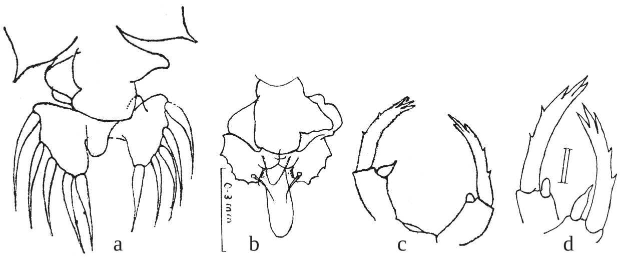


Fig. 1. *Labidocera pavo* Giesbrecht (a) Female dorsal view of metasome corners and urosome. (b) Female urosome dorsal view. (c) Female 5th pair of legs. (d) Female 5th pair of legs. (1.b, 1.d Silas and Pillai, 1973; Kasturirangan, 1963).

**Male**: Posterior margins of metasome end in points not drawn out. Right 5th leg chelate with a well-developed thumb, claw elongate, curved and with a blunt conical projection. Left leg with one outer marginal spine and three terminal subequal spines on the terminal segment, a distolateral spine on the subterminal segment, length 1.9 mm; (Fig. 2. a & b) and (Fig.2.1. c, d & e).

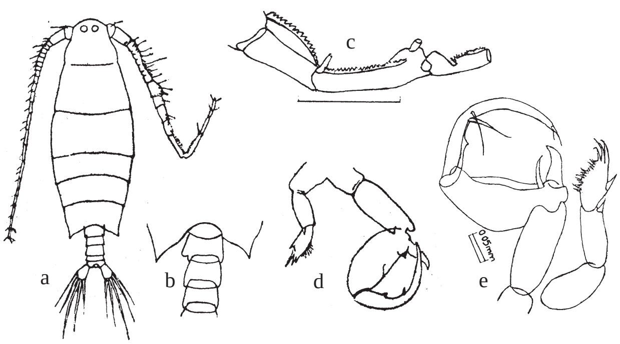


Fig. 2. *Labidocera pavo* Giesbrecht (a) Male dorsal view. (b) Male urosome dorsal view. (c) Male 1st antenna. (d) Male 5th pair of legs. (e) Male 5th pair of legs. (2.b, 2.c, 2.e, Silas and Pillai, 1973; Kasturirangan, 1963).

### Genus *Pontella*

Cephalosome with lateral hooks, usually without a crest, one pair of dorsal cuticular eye lenses and ventral eye lens present; rostrum bifurcate with short rami and with distinct lens, which are well developed in male than in female. 5th pair of legs biramous in female, reduced or sometimes asymmetrical; uniramous in male, right leg chelate with stout finger and thumb.

**1. *Pontella danae*** Giesbrecht, var. ***ceylonica***, Thompson & Scott **Female**: Urosome 2-segmented, genital segment with various outgrowths and concealing the urosome segments in dorsal view; 1st antennae alike on the two sides. Corners of metasome slightly asymmetrical, the left one a little longer; right caudal ramus distinctly larger and bearing a vertical crest-like extension visible in lateral view; left 5th leg distinctly longer with 2 outer spines on exopodite one of which is very clear; length 3.4 mm; (Fig.1. a, b, c & d) and (Fig. 1.2. a, b & c).

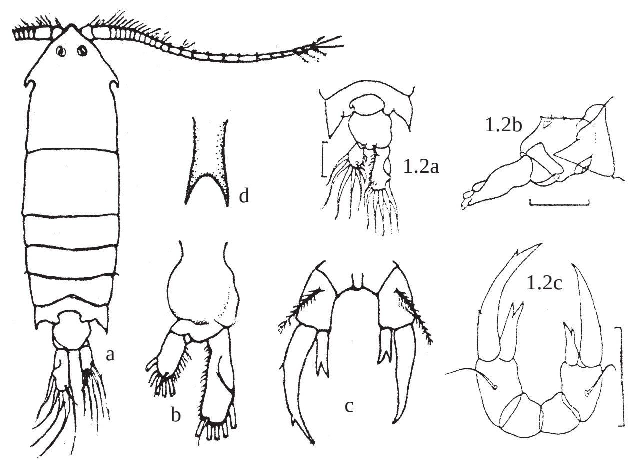


Fig. 1. *Pontella danae* Giesbrecht (a) Female dorsal view, *variety ceylonica*. (b) Female urosome dorsal view, *variety ceylonica*. (c) Female 5th pair of legs, *variety ceylonica*. (d) Female rostrum, *variety ceylonica*.

Fig. 1.2. *Pontella danae ceylonica*. (a) Female urosome dorsal view. (b) Female urosome lateral view. (c) Female 5th pair of legs. (1.2a, 1.2b, 1.2c Silas and Pillai, 1973; Kasturirangan, 1963).

**Male**: Body robust; dorsal eye lenses, ventral lens and rostral lens well developed; antennae geniculate; segment 14 with a long dorsal spine carrying a small flagellum at tip; segment 18 with dorsal toothed plate. Urosome 5-segmented, right 5th leg chelate; hand of chela with a well developed conical thumb; inner margin of hand provided with a squared process towards base of thumb; externally another conical spine present turned inwards; finger with a crescentic outgrowth at its inner mid-margin and terminates in a small hook which carry a seta; left 5th leg: terminal segment with 2 outer marginal spines and 2 distal spines, outer distal spine curved with serrated margin; inner margin of segment with setose hairs; subterminal segment with a disto-lateral spine. Length 3.1 mm; (Fig. 2. a & b) and (Fig. 2.1. a, b, c & d).

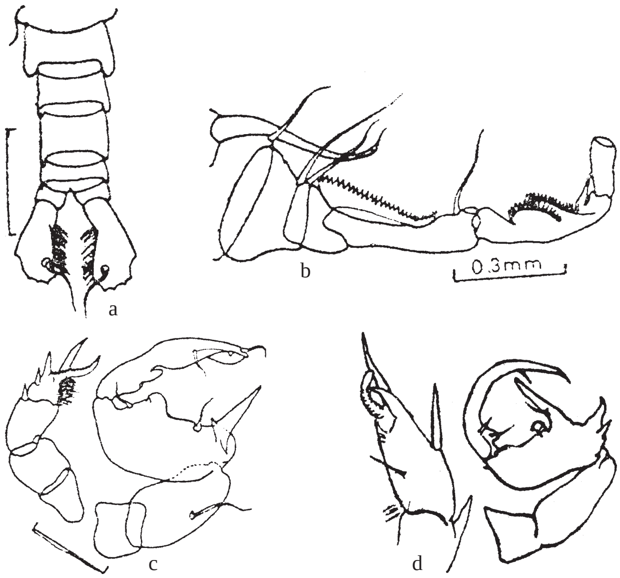



Fig. 2. *Pontella danae* Giesbrecht (a) Male urosome dorsal view. (b) Male 1st antenna. (c) Male 5th pair of legs. (d) Male 5th pair of legs. (2.a, 2.b, 2.c Silas and Pillai, 1973; Kasturirangan, 1963).

**2. *Pontella investigatoris*** Sewell, **Female**: Body robust; lateral cephalic hooks absent; dorsal eye lenses developed; rostrum bifurcate; urosome 2-segmented, genital segment with a conical lobe and rounded tip on its right side; posterior margin produced ventrally into a lobe extending to the middle of caudal rami; caudal setae short and bulbous at base; 1st antennae 23 segments; 5th legs asymmetrical; exopod with two outer marginal spines and terminates in three subequal spines, median spine longest; endopod asymmetrical, on left leg rounded and on right leg long and produced at its tip.

**Male**: Body robust; well-developed dorsal eye lenses, ventral lenses and rostral lenses; urosome 5-segmented; caudal rami asymmetrical, right ramus stout. Right antenna geniculate; segments 18 and fusion segments 19-21 carrying sharp denticulate plates on their dorsal margins; segment 14 with a long spine and a small flagellum at its tip;2 toothed plates on segments 19-21; 5th right leg chelate: thumb is a well developed, curved stout spine; inner margin of hand with a quadrate process, dorsal margin with a seta at its base; claw curved, elongated with 3 inner marginal and 1 outer distal spine; left leg: terminal segment short with 1 outer marginal spine, 2 terminal spines and a flagelliform process; inner margin of segment provided with 2 patches of hairs; subterminal segment with a distolateral spine; (Fig.1. a, b & c).

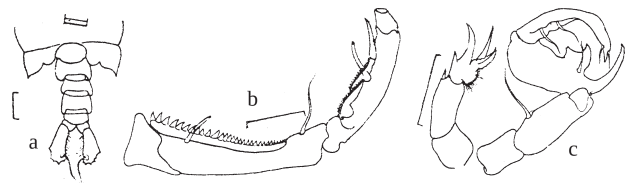



Fig. 1. *Pontella investigatoris* Sewell (a) Male urosome dorsal view. (b) Male 1st antenna. (c) Male 5th pair of legs. (Silas and Pillai, 1973)

Family **PSEUDODIAPTOMIDAE** Sars, 1902

Genus ***Pseudodiaptomus***

5th legs uniramous in female and usually in male also, rarely with only indistinct indications of the endopod in male. 1st antennae in female 20-22 segments.

**1. *Pseudodiaptomus annandalei*** Sewell **Female**: Urosome 4-segemented, 1st antennae alike on two sides. Genital segment with a prominent spine on each side pointing outwards; length 1.18 mm; (Fig.1. a, b, c, d & e).

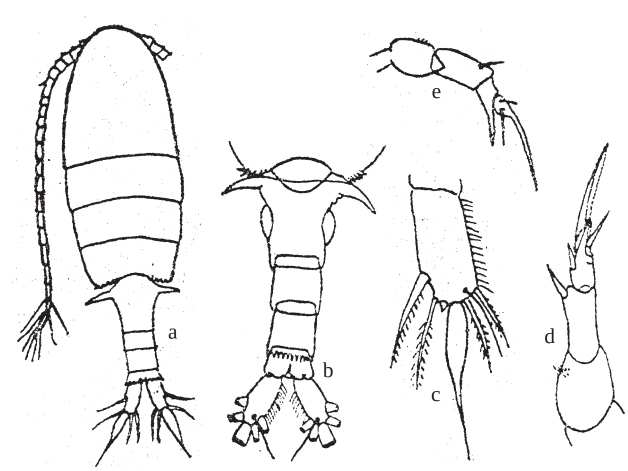



Fig. 1. *Pseudodiaptomus annandalei* Sewell (a) Female dorsal view. (b) Female urosome and part of metasome dorsal view. (c) Female caudal ramus and setae. (d) Female 5th leg of one side. (e) Female 5th leg. (1.b, 1.d Pillai, 1976; Kasturirangan, 1963).

**Male**: Urosome, 5-segmented, 1st antennae geniculate on the right side. 5th legs uniramous, length 1.09 mm; (Fig. 2. a & b).

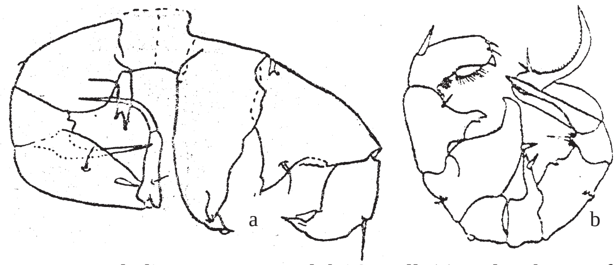



Fig. 2. *Pseudodiaptomus annandalei* Sewell (a) Male 5th pair of legs anterior view. (b) Male 5th pair of legs dorsal view. (2.b Pillai, 1976; Kasturirangan, 1963).

**2. *Pseudodiaptomus serricaudatus*** (T. Scott) **Female**: Genital segment without laterally pointing spines, slightly asymmetrical, the posterior margin produced more backwards on the right than on the left; all urosome segments with a regular row of triangular teeth on posterior margin, length 0.9 to 1.2mm; (Fig. 1. a, b, c, d, e, f & g).

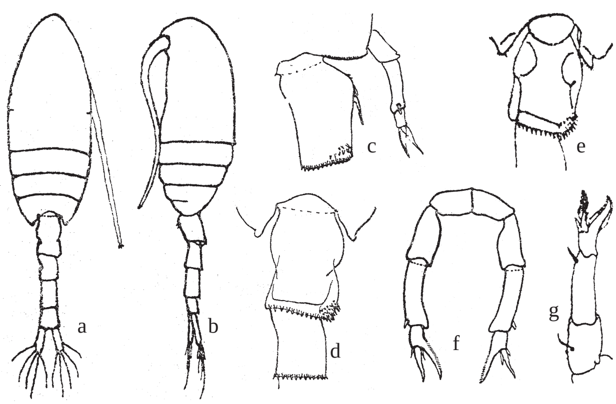



Fig. 1. *Pseudodiaptomus serricaudatus* (T. Scott) (a) Female dorsal view. (b) Female lateral view. (c) Female dorso-lateral view of last metasome and genital segments; 5th leg of right side is shown. (d) Female Dorsal view of genital and succeeding segments with triangular teet on posterior margin. (e) Female urosome lateral view. (f) Female 5th pair of legs. (g) Female 5th leg. (1.e, 1.g Pillai, 1976; Kasturirangan, 1963).

**Male**: 5th legs are highly complex as figured, left leg bear a long blade-like endopod, length 0.9-1.1 mm; (Fig. 2. a & b).

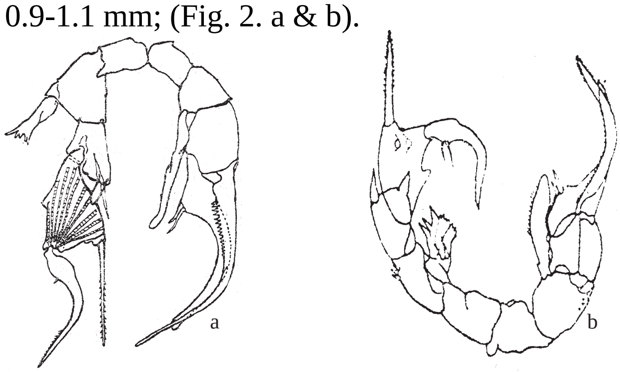



Fig. 2. *Pseudodiaptomus serricaudatus* (T. Scott) (a) Male 5th pair of legs anterior view. (b) Male 5th pair of legs dorsal view. (2.b Pillai, 1976; Kasturirangan, 1963).

Family **TEMORIDAE** Giesbrecht, 1893

Genus ***Temora***

Body short, compact, and head-end massive, caudal rami over six times as long as broad.

**1. *Temora turbinata*** (Dana) **Female**: Urosome 3-segmented, 5th legs 3-segmented and symmetrical. Posterior margin of metasome rounded; length 1.50 mm; (Fig. 1.a & b).

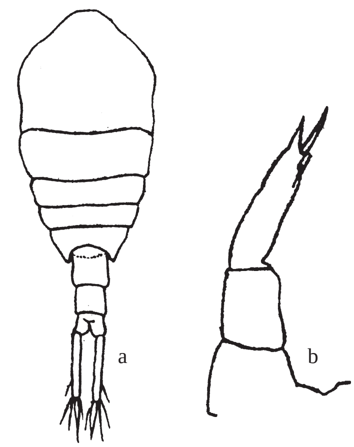



Fig. 1. *Temora turbinata* (Dana) (a) Female dorsal view. (b) Female 5th leg. (Kasturirangan, 1963).

**Male**: Urosome 5-segmented, 5th legs 3-segmented and asymmetrical, the left leg forms a chela. Posterior margin of metasome rounded, length 1.40 mm; (Fig. 2.a & b).

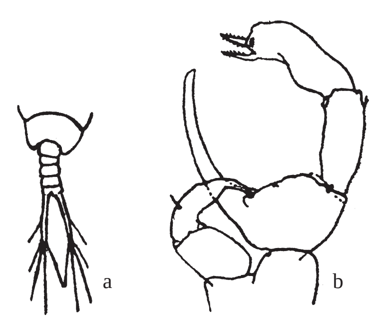



Fig. 2. *Temora turbinata* (Dana) (a) Male urosome dorsal view. (b) Male 5th pair of legs. (2.a Dakin and Colefax, 1940; Kasturirangan, 1963).

Order **CYCLOPOIDA** Burmeister, 1834

Family **CYCLOPIDAE** Dana, 1846

Subfamily **CYCLOPINAE** Sars, 1914

Genus ***Mesocyclops***

Body slender and clearly demarcated into anterior and posterior parts. Receptaculum seminis malleiform. Caudal rami relatively short ranging between 2.5-3.5 times as long as wide. 5th leg 2-segmented, distal segment with long seta and short spine (Fig. 1. a, b & c).

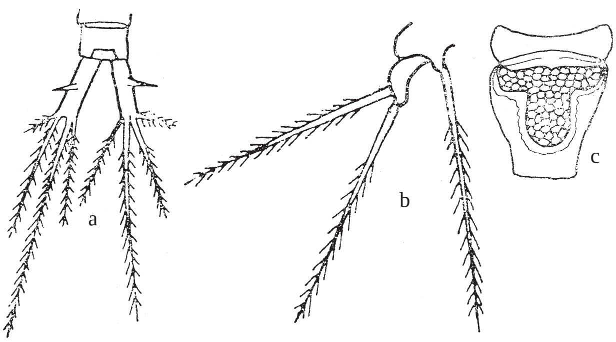



Fig. 1. *Mesocyclops* sp (a) Female caudal furca and furcal setae. (b) Female 5th leg. (c) Female receptaculum seminis. (Seghal, 1983).

***1. Mesocyclops (Mesocyclops) leuckarti*** Claus **Female**: Antennae 17-segmented and reaching to the posterior end of second thoracic segment, spine formula 3,4,4,3. Abdominal segments 4; receptaculum seminis large with a wide posterior sac. Caudal rami 2.9-3.2 times as long as wide; furcal setae 5. Each ramus inner apical seta more than twice the length of outer one; median apical seta long and well developed. 5th leg large, inner setiform spine on distal segment slightly shorter than apical seta. Average body length 0.87-1.21 mm; (Fig. 1.a, b, c, d & e).

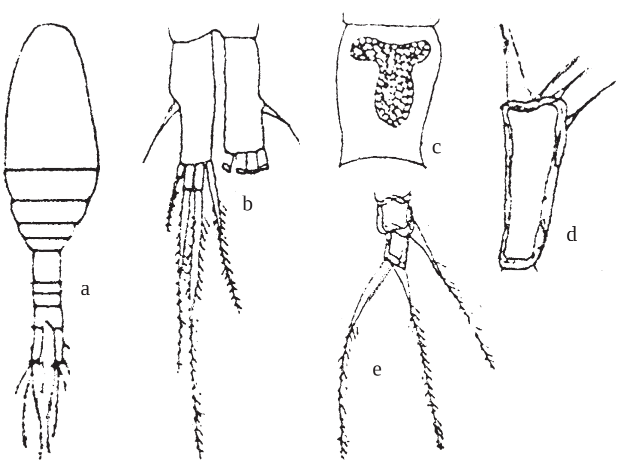



Fig. 1. *Mesocyclops (Mesocyclops) leuckarti* Claus (a) Female dorsal view. (b) Female caudal furca and setae. (c) Female receptaculum seminis. (d) Female distal segment of 1st antenna. (e) Female 5th leg. (Seghal, 1983).

**Male:** Antennae 16-segmented. Abdominal segments 4; 5th leg with short inner spine and two long setae; inner spine inserted in the middle of distal segment. Length 0.82-0.89 mm; (Fig. 2. a).


Fig. 2. *Mesocyclops (Mesocyclops) leuckarti* Claus (a) Male 5th leg. (Seghal, 1983).

Family **OITHONIDAE** Dana, 1852

Genus ***Oithona***

Cuticular eye-lenses not present on the cephalosome. Body not depressed cyclopoid form. Genital segment only on a little larger than the other urosome segments, maxillipeds and 2nd maxillae slender, covered with numerous spiny bristles. **Females**: Metasome very slender, fusiform; head terminating in front in a pointed rostrum; urosome 5-segmented; genital segment a little wider than the other urosome segments. **Males**: Metasome not so slender, smaller in length; head-end truncate, without rostrum; each 1st antennae twice geniculate with fewer setae than in females; urosome 6-segmented, genital segment wider than the other urosome segments.

**1. *Oithona rigida*** Giesbrecht **Female**: Rostrum bent down, not visible in dorsal view; body length less than 1 mm; Antennae reach up to the end of 3rd metasome segment only; outer marginal

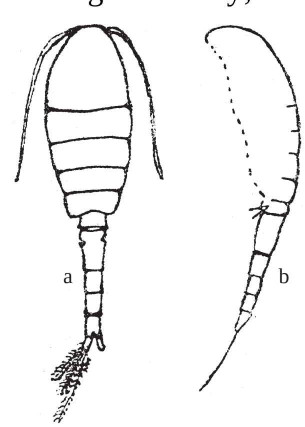



Fig. 1. *Oithona rigida* Giesbrecht (a) Female dorsal view. (b) Female lateral view. (Kasturirangan, 1963)

spines are 3, 3, 3, 2 in terminal exopod segments of legs 1 to 4; body much pigmented usually; apical setae of caudal rami not greatly elongated but coarsely plumose forming a fan; length 0.75 to 0.85 mm; (Fig. 1.a & b).

**Male**: Antennae twice geniculate; sheathing base appears to be present semicircular process is absent. Outer marginal spines are 3, 3, 3, 2 in terminal exopod segments of legs 1 to 4; length 0.7 mm; ***Oithona rigida*** is the commonest species of *Oithona* in inshore waters.

**2. *Oithona brevicornis*** Giesbrecht **Female**: Antennae reach up to 2nd metasome segment only; outer marginal spines are 3, 3, 3, 2 in terminal exopod segments of legs 1 to 4; the two longer setae on each caudal ramus show a peculiar crossed arrangement; length 0.6 mm; (Fig. 1. a).

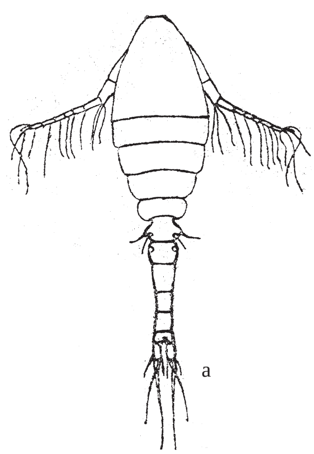



Fig. 1. *Oithona brevicornis* Giesbrecht (a) Female dorsal view. (Kasturirangan, 1963).

**Male**: Antennae twice geniculate; neither proximal sheath nor distal semicircular process is present; outer marginal spines are 3, 3, 3, 2 in terminal exopod segments of legs 1 to 4; length 0.55 mm.

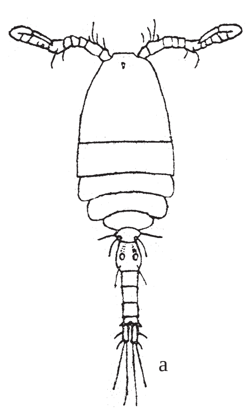



Fig. 2. *Oithona brevicornis* Giesbrecht (a) Male dorsal view. (Kasturirangan, 1963).

Order **HARPACTICOIDA** Sars, 1903

Family **CLYTEMNESTRIDAE** Scott, 1909

Genus ***Clytemnestra***

Body depressed, with angular projection at the posterior corners of the cephalosome and the next three segments, 5th legs long, narrow, 2-segmented, tipped with setae and without the characteristic inward expansion of the basal segment in Harpacticoida.

***1. Clytemnestra scutellata*** Dana **Female**: Exopod of 2nd antenna represented by two long setae; 1st antenna 8-segmented; caudal rami twice as long as broad; apical caudal setae quite short in females; length 1.07 to 1.30 mm; (Fig. 1. a, b, c, d, e & f).

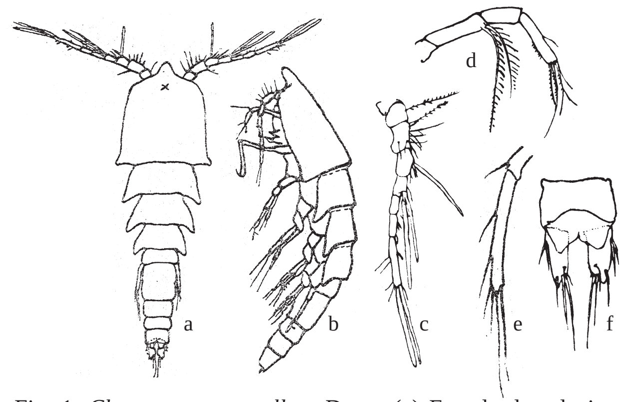



Fig. 1. *Clytemnestra scutellata* Dana (a) Female dorsal view. (b) Female lateral view. (c) Female 1st antenna. (d) Female 2nd antenna. (e) Female 5th leg. (f) Female caudal rami and anal segment. (Kasturirangan, 1963).

**Male**: Apical caudal setae very long in males, caudal rami twice as long as broad, length 1.07 – 1.30 mm; (Fig. 2. a).

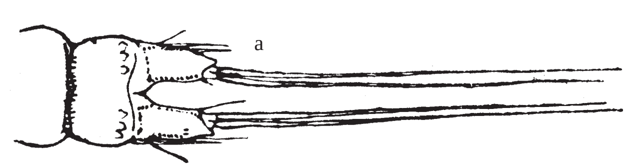



Fig. 2. *Clytemnestra scutellata* Dana (a) Male last two segments of urosome and caudal rami. (Kasturirangan, 1963)

Family **ECTINOSOMATIDAE** Sars, 1903

Genus ***Microsetella***

Endopods of 2nd legs not elongated; body fusiform; caudal setae very long.

**1.** ***Microsetella norvegica*** (Boeck) **Female**: Caudal rami as long as broad, inconspicuous, 2nd antennae with 3-segmented exopodite, small in size, less than 0.85mm. The inward expansion of the basal of the 5th leg bears one short and one long seta; caudal setae about as long as the body; length of female 0.35 to 0.53mm; (Fig. 1. a, b, c & d).

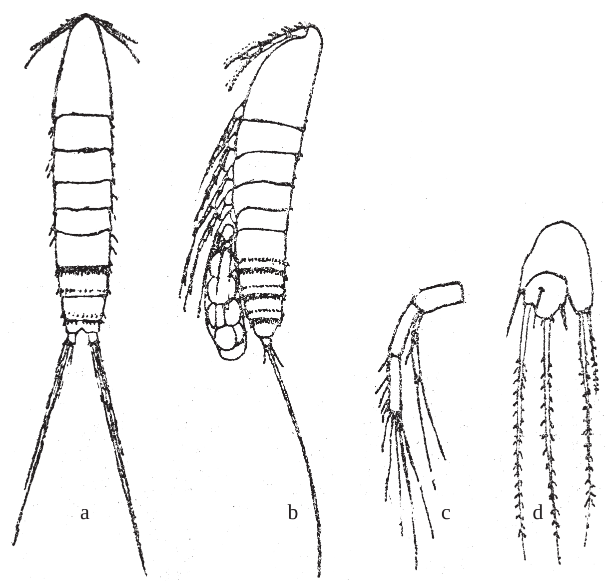



Fig. 1. *Microsetella norvegica* (Boeck) (a) Female dorsal view. (b) Female lateral view. (c) Female 2nd antenna. (d) Female 5th leg. (Kasturirangan, 1963).

**Male**: Second antennae with 3-segmented exopodite, length of male 0.33 to 0.42 mm; (Fig. 2.a).

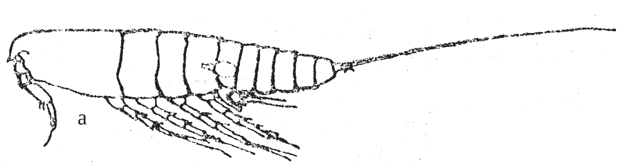



Fig. 1. *Microsetella norvegica* (Boeck) (a) Male lateral view. (Kasturirangan, 1963).

Family **EUTERPINIDAE** Brian, 1921

Genus ***Euterpina***

Body not depressed, 5th legs plate-like; without the characteristic inward expansion of the basal segment in Harpacticoida.

**1.** ***Euterpina acutifrons*** (Dana): **Female**: Body subpyriform; cephalosome drawn out in front into a greatly prominent rostral projection, acute at the tip; 5th legs formed by two undivided juxtaposed plates in the female, length of female 0.5 to 0.8 mm; (Fig. 1.a, b, c & d).

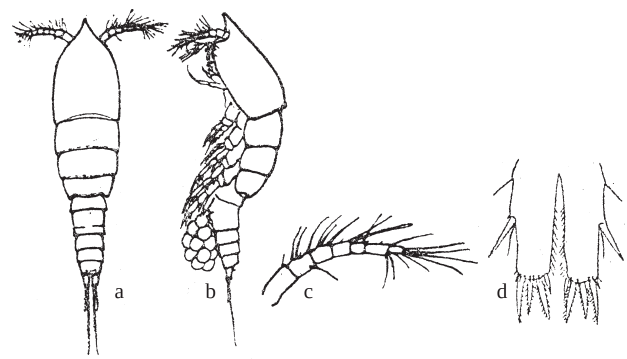



Fig. 1. *Euterpina acutifrons* (Dana) (a) Female dorsal view. (b) Female lateral view. (c) Female 1st antenna. (d) Female 5th pair of legs. (1.d Dakin and Colefax, 1940; Kasturirangan, 1963).

**Male**: 5th legs formed by two undivided juxtaposed plates coalesced in the middle in male; length of male 0.5 to 0.66 mm; (Fig. 2.a, b & c).

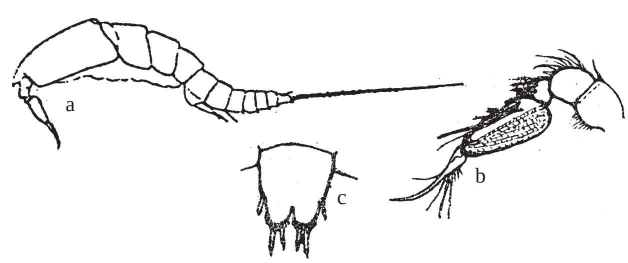



Fig. 2. *Euterpina acutifrons* (Dana) (a) Male lateral view. (b) Male 1st antenna. (c) Male 5th pair of legs. (2.a Dakin and Colefax, 1940; Kasturirangan, 1963).

Family **LONGIPEDIIDAE** Sars, 1903

Genus ***Longipedia***

5th pair of legs with the basal segment possessing the inward expansion characteristic of the Harpacticoida. Endopods of 2nd legs greatly elongated; inward expansion of 5th legs narrow, curved and pointed.

**1.** ***Longipedia weberi*** A. Scott **Female**: Anal operculum with the central tooth a little longer than the two teeth on each side length 0.95 mm; (Fig.1. a, b, c, d & e).

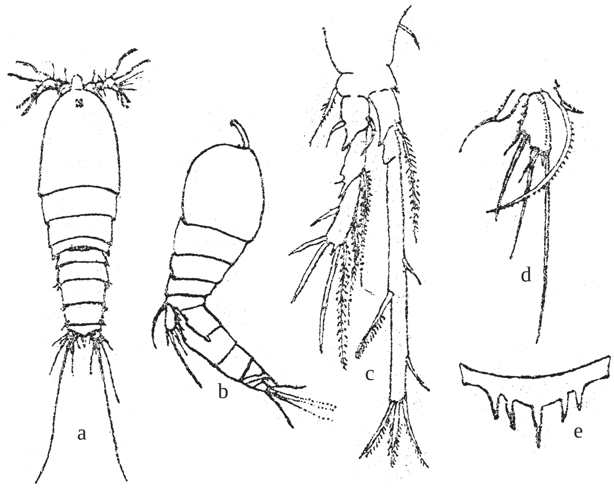



Fig. 2. *Longipedia weberi* A. Scott (a) Female dorsal view. (b) Female lateral view. (c) Female 2nd leg. (d) Female 5th leg. (e) Female anal operculum. (Kasturirangan, 1963)

Family **MACROSETELLIDAE**

Genus ***Macrosetella***

Endopods of 2nd legs not elongated; body fusiform; caudal setae very long.

***1. Macrosetella gracilis*** (Dana) **Female**: Caudal rami slender, cylindrical, over 4 times as long as broad; 2nd antennae without any exopodite; larger in size, over 1.0 mm; caudal setae about as long as the body; length 1.4 to 1.5 mm., (Fig.1.a & b).

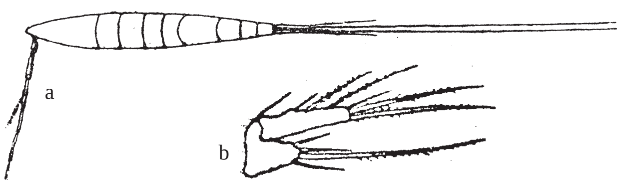



Fig. 1. *Macrosetella gracilis* (Dana) (a) Female dorsal view. (b) Female 5th leg. (1.b Dakin and Colefax, 1940; Kasturirangan, 1963).

**Male**: Length 1.16 to 1.30 mm; (Fig.2.a & b).

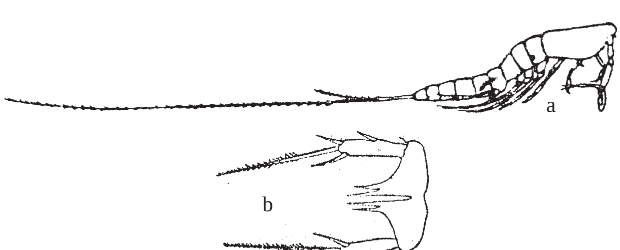



Fig. 2. *Macrosetella gracilis* (Dana) (a) Male lateral view. (b) Male 5th pair of legs. (2.b Dakin and Colefax, 1940; Kasturirangan, 1963).

Order **POECILOSTOMATOIDA** Thorell, 1859

Family **CORYCAEIDAE** Dana,1852

Genus ***Corycaeus***

Cuticular eye-lenses present on the cephalosome. Body not at all depressed; club-shaped; head round anteriorly, usually the last metasome segment and always the penultimate segment provided with tailward prolongations or 'lappets'; 2nd antennae stout and 3-segmented, subchelate, larger in the males than in the females, single egg-sac borne dorsally on the genital segment; caudal rami styliform. The two free metasome segments usually not fused together; urosome 2-segmented; no beak-shaped process on the ventral surface.

**1. *Corycaeus danae*** Giesbrecht **Female**: Lappets of metasome long, but not reaching up to the end of genital segment in the female; genital segment over hangs the anal segment in the female as seen in lateral view; length of female 1.6 -1.7 mm; (Fig. 1.a, b & c).

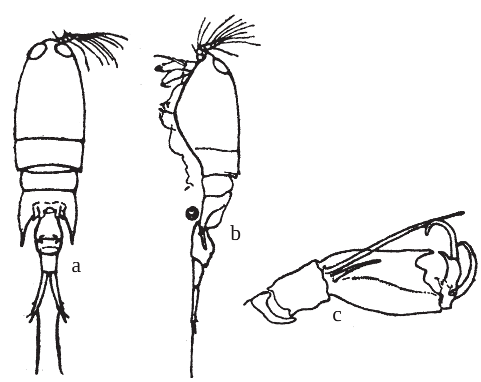



Fig. 1. *Corycaeus danae* Giesbrecht (a) Female dorsal view. (b) Female lateral view. (c) Female 2nd antenna. (Kasturirangan, 1963).

**Male**: Lappets of metasome long but not reaching up to the middle of the genital segment. Length of male 1.4- 1.5 mm; (Fig. 2. a & b).

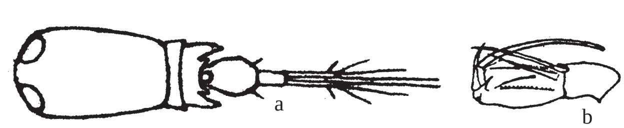



Fig. 1. *Corycaeus danae* Giesbrecht (a) Male dorsal view. (b) Male 2nd antenna. (Kasturirangan, 1963).

Family **ONCAEIDAE** Giesbrecht, 1893

Genus ***Oncaea***

Cuticular eye-lenses not present on the cephalosome. Body not depressed, of cyclopoid form; genital segment conspicuously enlarged, succeeding segement inconspicuous, maxillipeds three segmented, subchelate forming powerful grasping organs in both sexes.

**1. *Oncaea venusta*** Philippi **Female**: Second free metasome segment not raised into a hump; anterior part of the body obovate in the female; genital segments followed by 3 segments which are closely telescoped together; length of female 1.1 to 1.27mm; (Fig. 1. a).

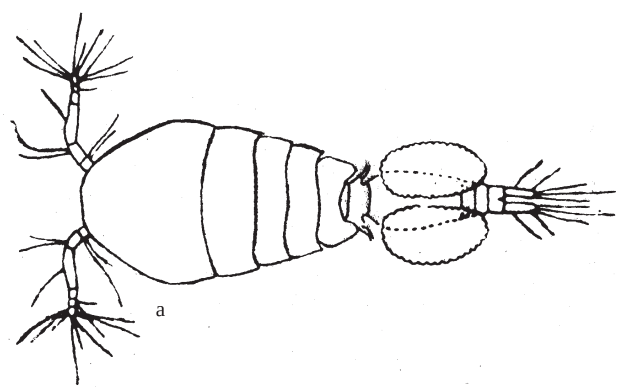



Fig. 1. *Oncaea venusta* Philippi (a) Female dorsal view. (Kasturirangan, 1963).

**Male**: Anterior part of the body less wide in the male; genital segment more conspicuously enlarged in the male than in the female and followed by 4 segments which are closely telescoped together; length 0.7 to 1.00 mm; (Fig. 2. a & b).

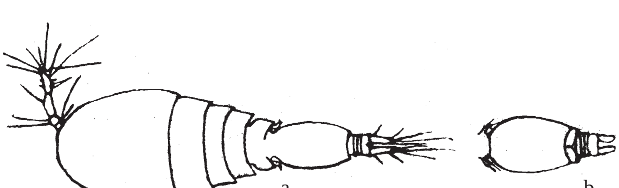



Fig. 2. *Oncaea venusta* Philippi (a) Male dorsal view. (b) Male urosome ventral view. (Kasturirangan, 1963).

Subclass **THECOSTRACA** Gruvel, 1905

Infraclass **CIRRIPEDIA** Burmeister, 1834

Superorder **THORACICA** Darwin, 1854

Order **SESSILIA** Lamarck, 1818

Suborder **BALANOMORPHA** Pilsbry, 1916

Superfamily **BALANOIDEA** Leach, 1817

Family **BALANIDAE** Leach, 1817

Scuta and terga articulated, freely movable and furnished with depressor muscles. Rostrum with radii, labrum notched in the middle. Third cirrus resembles the second cirrus. Illustrations on the external morphology, appendages and reproduction in barnacles are given in Fig. 1.a.

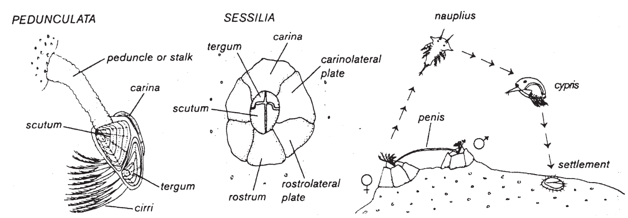



Fig. 1.a. External morphology, appendages and reproduction in barnacles. (Richmond, 1997).

Genus ***Balanus***

Shell cylindrical or conical. Composed of 6 compartments, opercular valves sub-triangular and as wide as orifice.

**1. *Balanus amphitrite*** var.***venustus*** Darwin: **Colour**: dirty white, with regular longitudinal violet-brown moderately broad stripes arranged in groups of 3 or 4, sheath dark brown, radii freckled in purple. Shell: conical, often depressed and laterally compressed in a few cases when attached to twigs. Basis calcareous with concentric ridges internally. Radii with crenated edges and septa denticulated on the lower side only. Scutum: articular ridge well developed. Tergum; angle of the apex very obtuse. Lower end of spur is square and nearly parallel with the basal margin. Labrum: Deep notched, teeth about

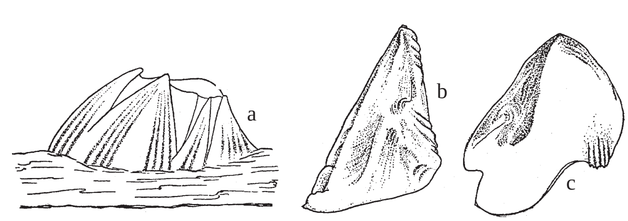



Fig. 1. (a) *Balanus amphitrite* var. *venustus*, Darwin attached to a twig. (b) Scutum internal view. (c) Tergum internal view of young. (Sundara Raj, 1927).

21; (Fig. 1.a, b, c, d, e, f, g & h). Very common, world wide in distribution. Largest is 16 mm along the basal diameter.

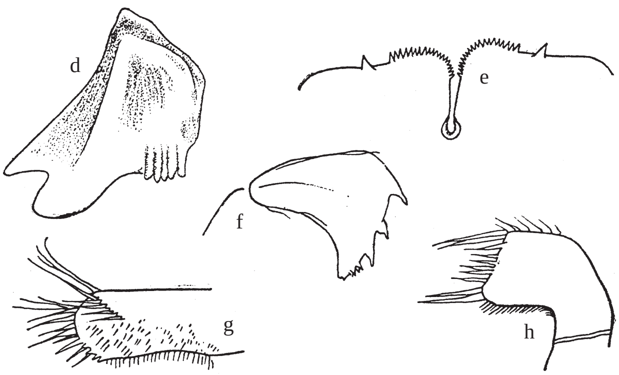



Fig. 1. *Balanus amphitrite* var. *venustus*, Darwin. (d) Tergum internal view of old animal. (e) Labrum. (f) Mandible. (g) Labial palp. (h) Maxilla. (Sundara Raj, 1927).

**2. *Balanus tintinnabulum*** (Linnaeus) var. ***communis*** Darwin: Radii transversely grooved throughout, walls stained inside with pale purple and the sheath with dark purple. Peripheral margin of the basis and the lower magin of the wall are ribbed inside. Growth ridges of the scutum are sometimes absent near the apex. Basis and radii penetrated by pores. Basal diameter is 65 mm; (Fig. 2.a, b, c, d & e). World wide in distribution.

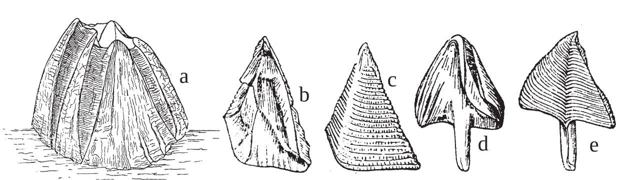



Fig. 2. (a) *Balanus tintinnabulum* (Linnaeus) var. *communis* Darwin. (b) Scutum internal view. (c) Scutum external view. (d) Tergum internal view. (e) Tergum external view. (Sundara Raj, 1927).

Superfamily **CORONULOIDEA** Leach, 1817

Family **CHELONIBIIDAE** Pilsbry, 1916

Genus ***Chelonia***

**1. *Chelonia testudinaria*** (Linnaeus): Characteristic turtle barnacle on the carapace of turtles seen lying on the island areas; (Fig. 1. a & b).

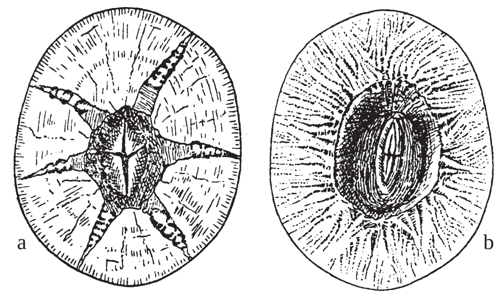



Fig. 1. (a) *Chelonia testudinaria* (Linnaeus) dorsal view. (b) ventral view. (Sundara Raj, 1927).

Order **PEDUNCULATA** Lamarck, 1818

Suborder **LEPADOMORPHA** Pilsbry, 1916

Family **LEPADIDAE** Darwin, 1852

Stalk and capitulum sharply marked off, peduncle flexible without calcareous plates. Scuta with an adductor muscle.

Genus ***Lepas***

Carina extending between the terga, ending below in a fork or disc. Scuta sub-triangular with their umbones at the rostral angle. Filaments beneath the basal articulation of the 1st cirri.

**1. *Lepas anserifera*** Linnaeus: Valves distinctly furrowed, especially the tergum. Right scutum has a well developed umbonal tooth; the left one has a small tooth, sometimes only a prominence. Occludent margin of the scuta arched and protuberant, 5 or 6 filaments on each side (Fig. 1. a & b).

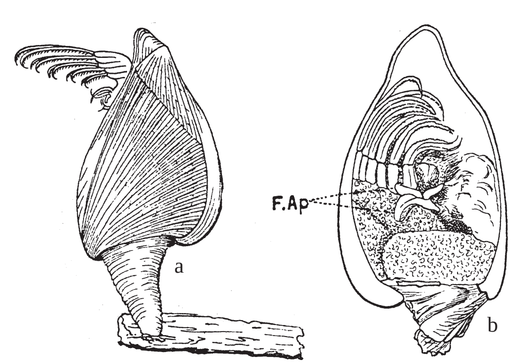



Fig. 1. (a) *Lepas anserifera* Linnaeus, dorsal view. (b) Internal view filamentary appendages. (Sundara Raj, 1927).

The nauplii and cypris stages of barnacles are often found in the plankton (Fig. 1. a, b, c, d & e).

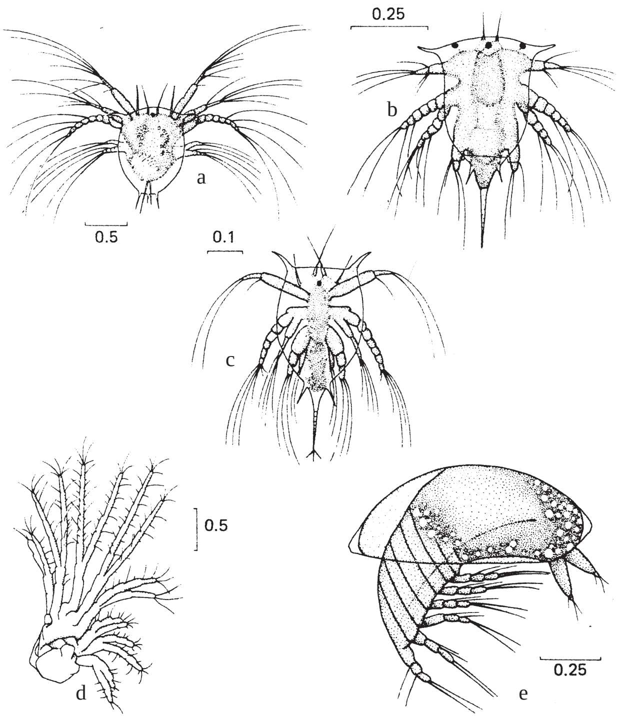



Fig. 1. Nauplii of barnacles (a, b & c). (d) Exoskeleton from molt of branacle. (e) Cypris larva of branacles. (Smith De Boyd, 1977).

Class **BRANCHIOPODA** Latreille, 1817

Subclass **PHYLLOPODA** Preuss, 1951

Order **DIPLOSTRACA** Gerstaecker, 1866

Suborder **CLADOCERA** Latreille, 1829

Small crustaceans distinguished by a bivalved carapace without a hinge, which is fused to two or more of the thoracic segments leaving the head free. Only 4 to 6 trunk limbs, single compound eye and a dorsal cavity below the carapace that serves as a brood pouch where the eggs are incubated. Second antennae with few joints and bearing plumose bristles that aid in locomotion.

Infraorder **CTENOPODA** Sars, 1865

Family **SIDIDAE** Baird, 1850

Genus ***Penilia***

**1. 1. *Penilia avirostris*** Dana **Female**: Body and legs covered by bivalve carapace, antennules of females small and truncated; sensory setae terminal. Head with prominent rostral points in females. The entire free carapace edged with spines; a larger spine at the inferoposterior angle of carapace. Six pairs of legs, the most posterior ones reduced. Length 0.5 to 1.2 mm; (Fig. 1.a & b).

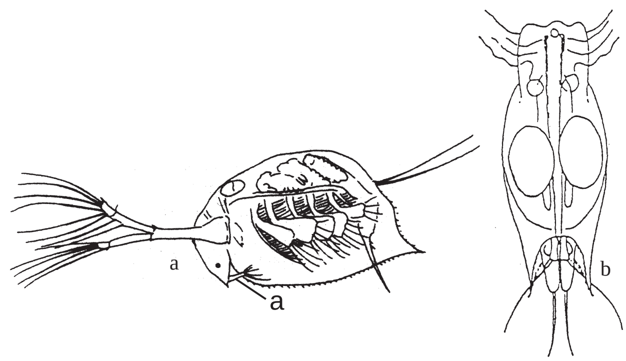



Fig. 1. *Penilia avirostris*. (a). Female with parthenogenic embryos, lateral view (b) Gamogenic female with resting embryos, dorsal view. (Egloff *et. al.,* 1997).

**Male:** Antennules as long as the carapace in adult males. Head round in males; strong hook at the distal end of the first leg. Copulatory organs longer than postabdomen in adults. Length 0.7 to 0.9 mm; (Fig. 2. a & b).

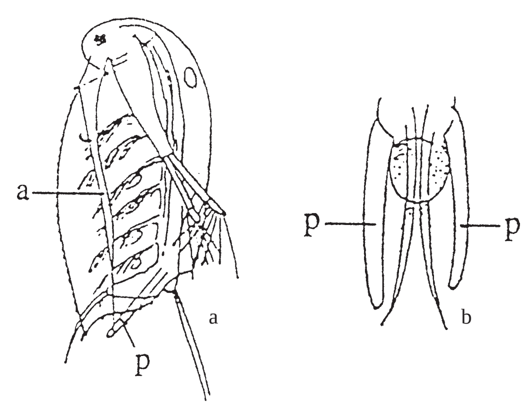



Fig. 2. *Penilia avirostris*. (a). Male lateral view. (b) Male ventral view. a - Antennule; p - penis. (Egloff *et. al.,* 1997).

Genus ***Diaphanosoma***

**1. *Diaphanosoma sarsi*** Fischer **Female**: Head large, without rostrum, fornix and ocellus; eyes large with lenses, cervical sinus present. Antennules small, truncated; with terminal olfactory setae and a slender flagellum. Dorsal ramus of antenna 2-segmented, ventral ramus 3-segmented. Postabdomen narrow without anal spines. Claw with three basal spines; length 0.8-0.94 mm; (Fig. 1. a).

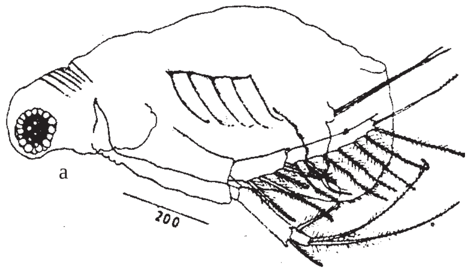



Fig. 1. *Diaphanosoma sarsi* Fischer (a). Female lateral view. (Michael & Sharma, 1988).

**Male**: Smaller than female; long antennules of length 0.33mm; olfactory setae laterally placed and hook on 1st foot. Average length of male 0.77mm.

Infraorder **ONYCHOPODA** Sars, 1865

Family **PODONIDAE** Mordukhai-Boltovskoi, 1968

Genus ***Evadne***

**1. *Evadne tergestina*** Claus **Female**: Body and legs not covered by bivalve carapace. Carapace converted into large brood sac, junction of head and body without dorsal depression and the body is oval in shape. Brood pouch from hemispherical to semi-oval in shape. Length 1.0 mm in females; (Fig. 1. a & b).

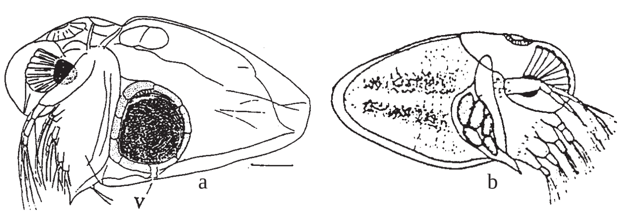



Fig. 1. *Evadne tergestina* Claus. (a) Gamogenic female with resting embryos, lateral view. (b) Female with parthenogenic eggs, lateral view. (1.b Wickstead, 1965; Egloff *et. al.,* 1997).

**Male**: Length 0.8 mm. (Fig. 2. a).

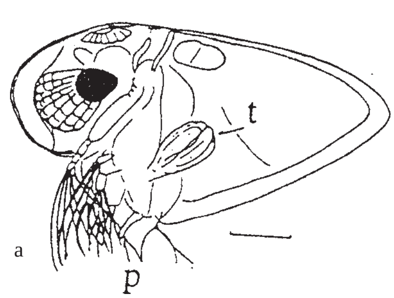



Fig. 2. *Evadne tergestina* Claus. (a) Male lateral view.
t - testes; v - vagina. (Egloff *et. al.,* 1997).

Class **MALACOSTRACA** Latreille, 1802

Subclass **EUMALACOSTRACA** Grobben, 1892

Superorder **PERACARIDA** Calman, 1904

Order **MYSIDA** Haworth, 1825

Family **MYSIDAE** Haworth, 1825

Small shrimp like crustaceans with a shield like carapace loosely covering the posterior part of thorax, not fused with more than three thoracic segments. Thoracic limbs with well developed exopodites, the 1st are the maxillipeds and the 2nd gnathopod. A rostrum and stalked eyes. Endopods of uropod with statocyst except some deep water forms. Eggs are carried in a brood pouch (marsupium) formed by the oostegites of the endopodites of thoracic limbs. Illustrations on the external morphology and appendages of a mysid are given in Fig.1.a & b.

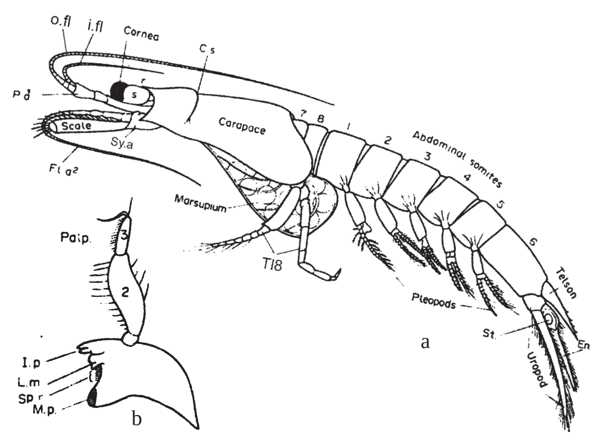



Fig. 1. (a) External morphology and appendages of a female mysid, lateral view. (pd): peduncle of a 3-segmented antennule with outer (o.fl.) and inner (i.fl) flagella; (sya): sympod of antenna; ($fla^2$): flagellum; (s): stalk of eye; (r): rostrum; (c.s): cervical sulcus; (7 and 8): 7th and 8th thoracic somites; ($t.l^8$): 8th thoracic limb; (en): endopod of uropod; (st): statocyst.

(b) Mandible with three segmented palp. (I.p.): incisor process; (L.m.): lacinia mobilis; (Sp.r): spine row: (M.p.): molar process. (Reymont, 1983).

Genus ***Mesopodopsis***

**1. *Mesopodopsis orientalis*** (W.M.Tattersall): Rostrum very short, perfectly semicircular. Thoracic limbs 3 to 8 with 5 to 9 carpopropodal segments. 4th pleopod of **male** with endopod nearly twice as long as the 1st segment of exopod, the spines on the 3rd exopod segment not spirally twisted. Telson with 4 lateral spines (Fig. 1. a), narrow distal part more than one-third the total length. Observed in mangroves and estuarine environments. Length 7 mm.

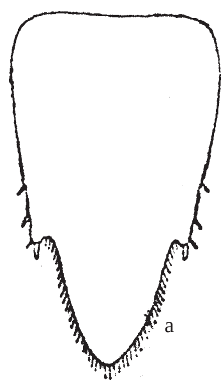



Fig. 1. *Mesopodopsis orientalis* (W.M.Tattersall) (a) Female telson. (Pillai, 1965).

***2. Mesopodopsis zeylanica*** Nouvel: Frontal plate angular, anterolateral angles produced into curved spines. Thoracic limbs 3 to 8 with 6 carpopropodal segments. 4th pleopod of **male** very long reaching far beyond the tip of telson, endopod very small, only half as long as the 1st segment of exopod, 3rd exopod segment with 2 long spines, the shorter of the two barbed and the longer spirally twisted. Telson with 4 lateral spines (Fig. 2.a), narrow distal part one-third the total length, armed with 50 to 55 teeth. Endopod of uropod without spine below statocyst. Length 5.6 mm.

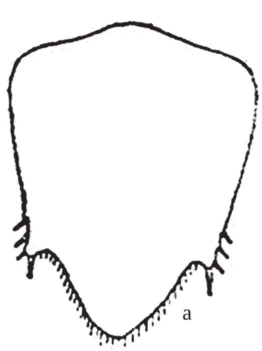



Fig. 2. *Mesopodopsis zeylanica* Nouvel (a) Female telson. (Pillai, 1965).

Genus ***Gastrosaccus***

**1. *Gastrosaccus dunckeri*** Zimmer **Male**: Shallow water form, peculiar bulging of the basal part of the eyestalk is characteristic. Posterior border of carapace with a pair of large forwardly directed lobes larger than those of any other species. Endopod of third pleopod of male 8-segmented, exopod 4-segmented, 4th segment with 2 subequal spines, the longer with a few strong barbs. Endopod of uropod with 18 spines. Telson with 15 lateral spines, some of them at intervals smaller than the adjacent ones, 2 spineless areas between the 1 st 2 and last 2 lateral spines (Fig. 1. a, b, c, d, e & f).

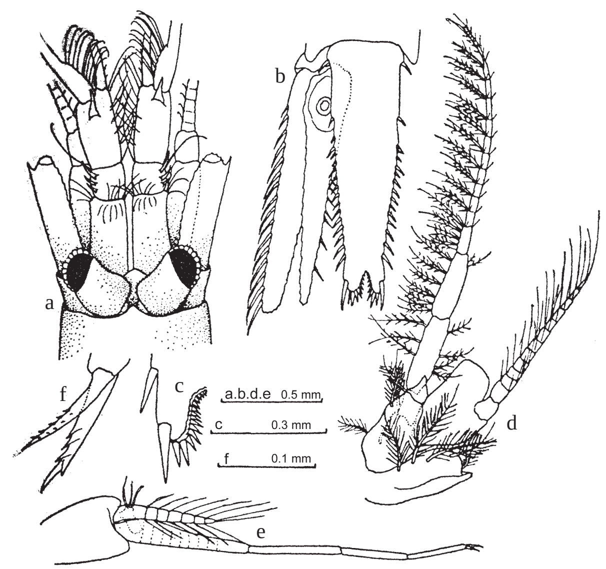



Fig. 1. *Gastrosaccus dunckeri* Zimmer (a) Male anterior part. (b) Male posterior part. (c) Male apical lobe of telson. (d) Male 8th thoracic limb. (e) Male 3rd pleopod. (f) Male 3rd pleopod tip of exopod. (Pillai, 1965).

Another common species of ***Gastrosaccus*** (**Female**) is also represented in Fig. 2. a, b & c.

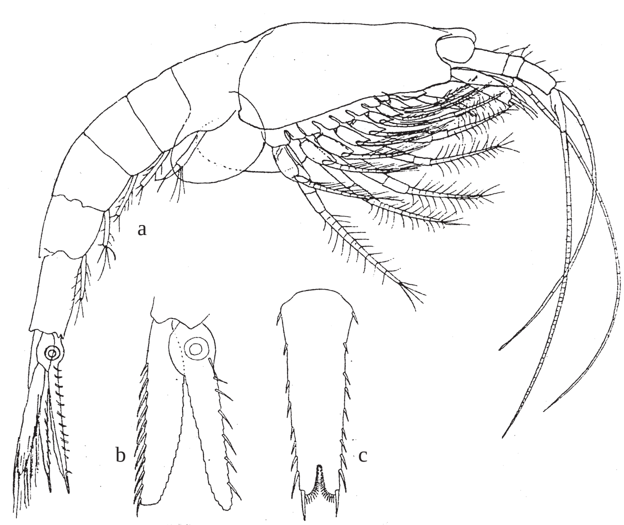



Fig. 2. *Gastrosaccus* sp (a) Female lateral view. (b) Female uropods. (c) Female telson. (Dakin and Colefax, 1940).

Order **AMPHIPODA** Latreille, 1816

Amphipods are generally small with a bilaterally compressed body, without carapace, sessile eyes, biramous antennules, pereopods 2-3 subchaelate and with 3 pairs of backward pointing uropods present on the tail. Found in a diversity of habitats from the upper shore to great depths. Illustrations on the external morphology and appendages of an amphipod are in Fig. 1 a.

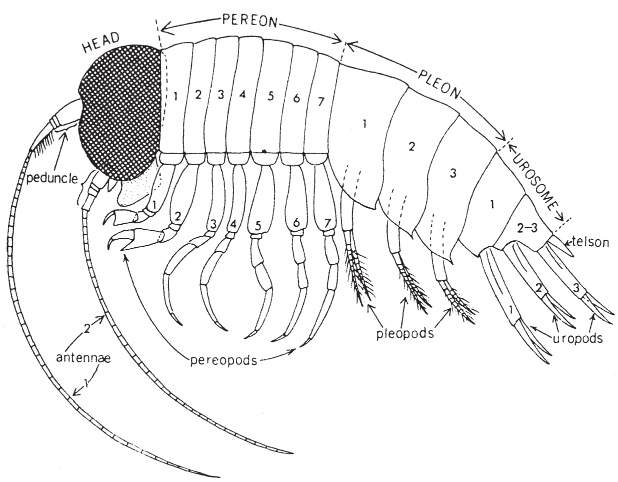



Fig. 1.a. External morphology and appendages of an amphipod, lateral view. (Richmond, 1997).

Suborder **GAMMARIDEA** Latreille, 1802

Family **GAMMARIDAE** Latreille, 1802

Gammaridae (Fig. 1.a) include the bulk of the large shallow water species while the hyperiidae (Fig. 1.b) are the transparent planktonic forms which live at all depths and also as a commensal (Fig. 1.b & 1. c).

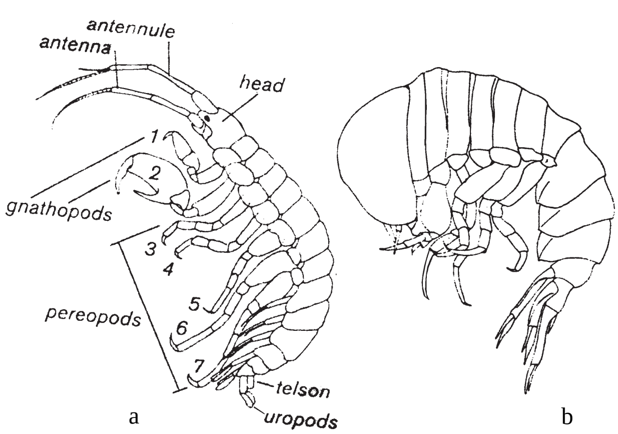



Fig. 1.(a) External morphology and appendages of a gammarid and (b) hyperrid amphipods, lateral views. (Richmond, 1997).

Family **MELITIDAE** Bousfield, 1973

Genus ***Melita***

**1.** ***Melita zeylanica*** Stebbing **Male**: Head without a rostrum, antero-inferior angle produced into an independent rounded lobe. Peraeon segments and first 3 pleon segments subequal. Coxal plates 1-4 with dorsal spinules. Posterolateral angles of the third pleon segment hook like. First antenna with 23-segmented flagellum and accessory flagellum is 4-segmented. Flagellum of second antenna is 7-8 segmented. Found very often in the mangroves (Fig. 1. a, b, c, d & e).

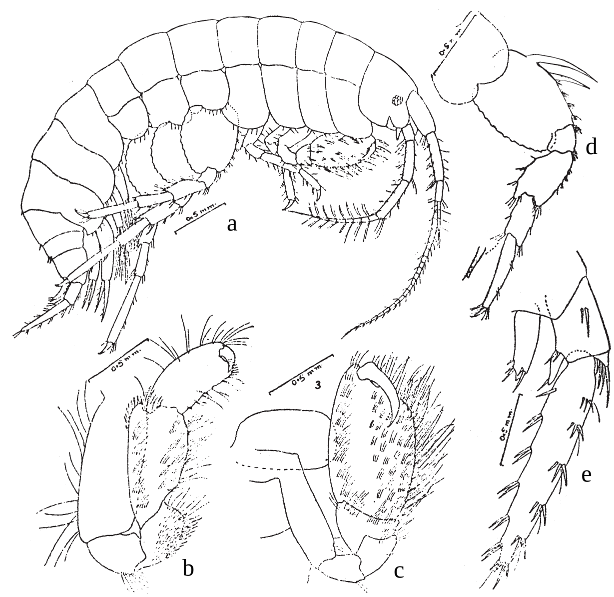



Fig. 1. *Melita zeylanica* Stebbing (a) Male, lateral view. (b) First pereiopod (c) Second pereiopod (d) Fifth pereiopod (e) Third uropod and telson. (Pillai, 1961).

Order **ISOPODA** Latreille, 1817

Isopods with dorsoventrally compressed body, lacking a carapace, eyes sessile, body is divided into narrowed segments – 7 thoracic and 6 abdominal, the antennules and antennae are always uniramous. Illustrations on the external morphology and appendages of an isopod are given in Fig. 1. a & b.

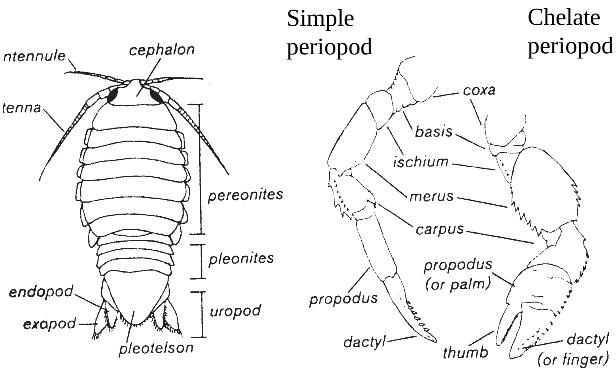



Fig. 1. External morphology and appendages of an isopod (a) dorsal view (b) Chelate and Simple pereiopod. (Richmond, 1997).

Suborder **FLABELLIFERA** Sars, 1882

Family **CIROLANIDAE** Dana, 1852

Genus: ***Cirolana***

**1.** ***Cirolana fluviatilis*** Stebbing: Body comparatively narrow, two and a half to 3 times as long as broad. Peraeon segments 4-7 with a row of teeth along the posterior border, 7th segment with 13 teeth. Pleon segments 3-5 also with a row of teeth, 11 on 4th and 5 on 5th; the median tooth on each segment larger than the others. Telson triangular, with nearly straight lateral borders. Dorsal side with 2 submedian teeth near the base followed by two parallel longitudinal rows of 3-4 denticles forming a pair of ridges.

Third segment of first peraeopod with 2 blunt teeth, 4th segment with 4, 5th segment not immersed and with a large curved blunt distal tooth.

Endopod of uropod distally rounded and exopod narrow. Colour semitransparent lemon yellow, with slight greenish tint. The tubercles turn rosy in spirit.

Very common in the estuarine regions of Kerala and Chilka lake. Sparingly obtained at Madras and Visakhapatnam. This species was reported from Vishakhapatnam as ***C. pleonastica***, but on re-examination the material was found to be ***C. fluviatilis***. Length 9.0 mm; (Fig.1. a & b).

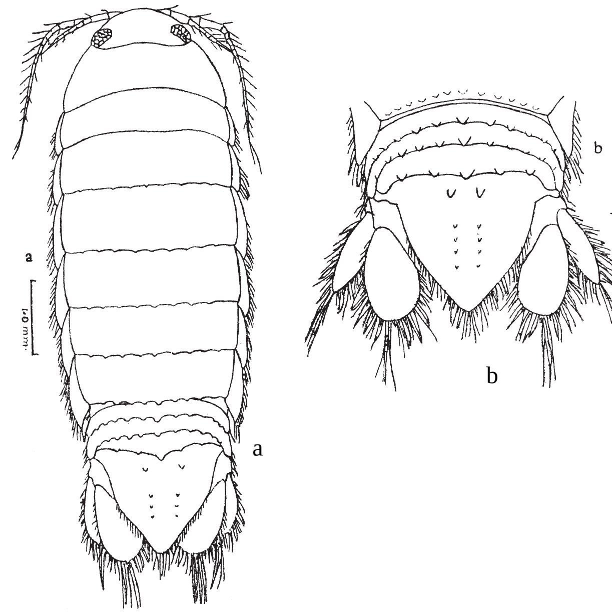



Fig. 1. *Cirolana fluviatilis* Stebbing (a) Female dorsal view. (b) Pleon and telson. (Pillai, 1961).

Family **SPHAEROMATIDAE** Latreille, 1825

Body oval-convex with pleon of two distinct free somites including telson. 1st antennae with peduncle of 3 articles and 2nd antennae with peduncle of 5 articles. Uropods lateral, exopod free and movable, endopod attached to peduncle immovable. The most important character of identification is the number and arrangement of tubercles on the posterior part of the body. Another obvious characteristic of this family is the ability to roll into a sphere when disturbed.

Genus ***Sphaeroma***

**1.** ***Sphaeroma terebrans*** Bate: Body elongate, oblong, broadest at the sixth segment. Posterior half of dorsal side coarsely granular, each granule carrying a bunch of long hairs. Border of segments hairy. Second peraeon segment shortest and fourth longest. Segments 3-7 with a transverse ridge placed in the anterior half on segment 3 but shifting successively backwards on the succeeding segments and becoming posterior submarginal on the seventh segment. Peraeon segments 5-7 with 4 equidistant posterior submarginal tubercles each carrying a bunch of long stiff hairs, submedian pair slightly longer than the lateral; some specimens with 4 indistinct tubercles on the fourth segment also. Composite pleon segment equal to the seventh peraeon segment, with 4 large tubercles as on the peraeon. Lateral parts with 3 oblique sutures. **Telson** - A broad based triangle, proximal median part bulged. The proximal region with 4 tubercles similar to those on the pleon and peraeon. Dorsal side of pleon and telson with pustules of various sizes, surmounted by hairs, giving the body a coarsely granular appearance. The successive tubercles on the peraeon, pleon and telson fall into 4 equidistant longitudinal rows.

Abundant in estuarine habitats, a true borer, body dirty brown grey, found in association with ***S. annandalei***, and very common in mangrove areas, length 15.3mm; (Fig. 1.a & b).

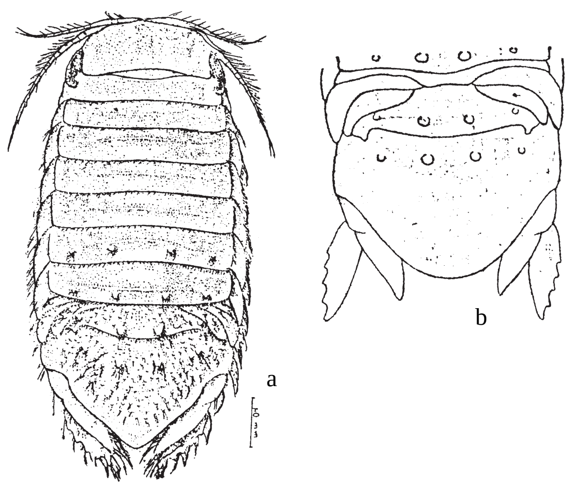



Fig. 1. *Sphaeroma terebrans* Bate (a) dorsal view (b) Pleon and telson. (Pillai, 1961).

**2. *Sphaeroma annandalei*** Stebbing: Body elongate, oblong, sides parallel. Peraeon segments subequal, each except the first with a transverse ridge. The ridges on segments 2-4 indistinct, on fifth very prominent, those on sixth and seventh broken up into 4 pairs of transversely elongated tubercles; tubercles of seventh segment more prominent, submedian pairs are larger.

Telson - Distal border semicircular, dorsal side proximately bulged and with 2 pairs of submedian tubercles followed by a median tubercle and flanked by 3 tubercles falling into a longitudinal row on either side. The median tubercle is generally with 3 small tubercles on either side. In large specimens the telsonic border is proximally ridge-like and distally crenulate and slightly curved upwards.

Body dark grey, with slight mottling. True timber borer, abundant in the backwater systems of India. Heaviest attack in the intertidal region, length 14.2 mm; (Fig. 2. a & b).

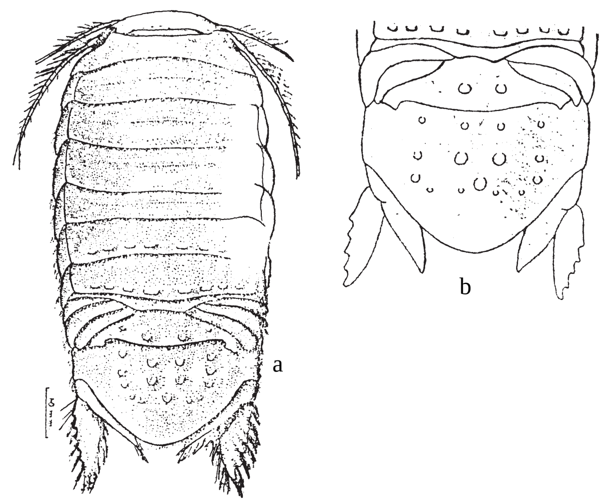



Fig. 2. *Sphaeroma annandalei* Stebbing (a) dorsal view (b) Pleon and telson. (Pillai, 1961).

**3. *Sphaeroma annandalei travencorensis*** Pillai: Body perfectly oblong, anterior border or cephalon prominently trilobed, antero-lateral borders raised and ridge-like. Each peraeon segment with a transverse ridge, the posterior ones broken up into 4 pairs of transversely elongated tubercles, those on seventh segment very high and wedge - shaped.

Pleon with 4 tubercles. Proximal middle part of telson with 5 tubercles but the lateral longitudinal row is composed of only 2 tubercles. The first submedian pair is slightly smaller than the second. The whole surface of telson is pustulose. Distal border perfectly rounded and ridge-like, the margins with blunt spines. Body grey with isolated brick red patches on the border of segments. Found abundant at Cochin backwater system, length 14.6 mm; (Fig. 3. a & b).

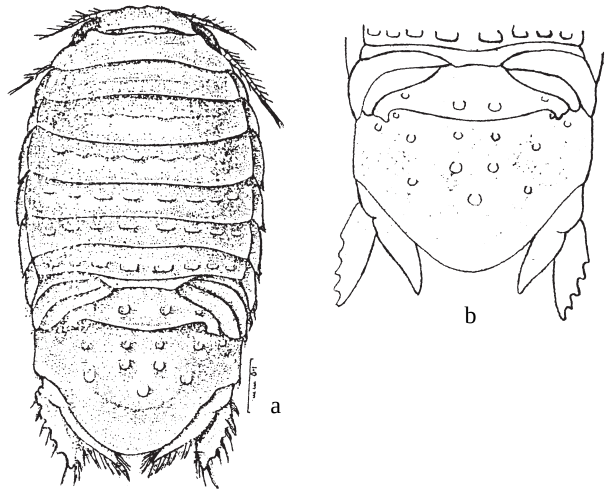



Fig. 2. *Sphaeroma annandalei travencorensis* Pillai (a) dorsal view (b) Pleon and telson. (Pillai, 1961).

Order **TANAIDACEA** Dana, 1849

Suborder **TANAIDOMORPHA** Sieg, 1980

Superfamily **TANAOIDEA** Dana, 1849

Family **TANAIDAE** Dana, 1849

Tanaidaceans inhabit mostly marine and brackish water environments occur in the estuaries of the east and west coasts of India and in mangroves. These epibenthic organisms enjoy worldwide distribution, high fecundity and short generation time. Their importance in estuarine shrimp farms as fodder organisms and as indicators of environmental health has been recognized recently.

**Genus** ***Tanais***

***1. Tanais philetaerus*** Stebbing **Male**: Body slightly narrowing towards the posterior end, head pear shaped, anterior part forming a narrow 'neck' behind the eyes. 1st free peraeon segments short, its anterolateral corners pointed. Pleon 5 segmented, 3rd and 4th segments together equal to the 2nd in length. 5th segment triangular and posteriorly cleft segments 1-3 with a dorsal transverse row of setae. 1st antenna 4-segmented, 2nd antenna 5- segmented carrying a stout tooth. Uropods 4-segmented, almost as long as pleon, 1st segment shortest.

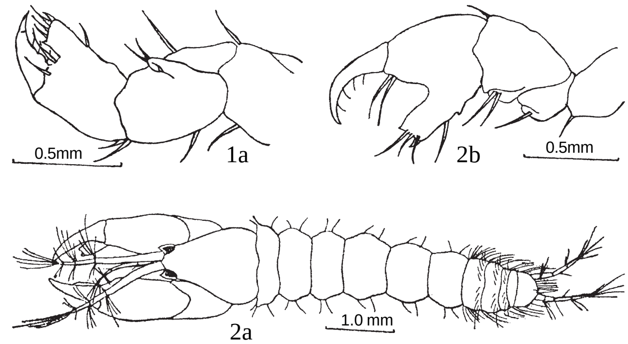



Fig. 1. *Tanais philetaerus* Stebbing (a) Female 1st pereiopod 2. (a) Male dorsal view. (b) Male 1st pereiopod. (Pillai, 1961).

Body dark grey, with profusely branched chromatophores forming patterns at the anterior and posterolateral aspects of the head and the posterior and lateral parts of the body segments. This species is very common in the Kerala backwaters and in the Mangalavanam Mangrove areas. Body length 4.0 mm. **Female's** 1st pereiopod is shown in Fig.1. a and **male's** dorsal view and first pereiopod in Fig. 2. a & b.

**2.** ***Apseudes chilkensis*** Chilton **Male:** Body length ranged from 5.15 to 7.5 mm. The transparent membraneous marsupial pouch is formed of the four pairs of oostegites arising from the base of the 2nd to 5th pairs of pereiopods. Sexual dimorphism is seen in chela of the advanced stages. Size and structure of chelae, 7th pair of pereiopods, pleopods, presence or absence of oostegites are helpful in identifying

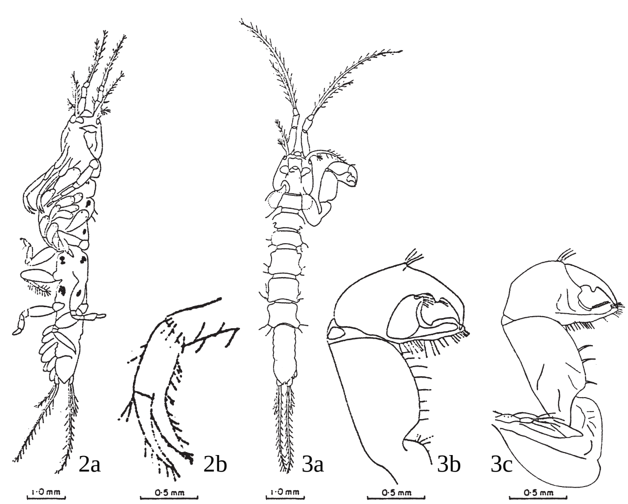



Fig. 2. *Apseudes chilkensis* Chilton (a) Female ventro-lateral view. (b) Female chela. 3. (a) Male dorsal view. (b) Male chela. (c) Male cheliped. (Vengayil *et. al.*, 1988).

the animal. It is a common tanaid from the backwaters of Kerala. Diagnostic characters of **female** are shown in Fig. 2. a & b and those of **male** in Fig. 3. a, b & c.

Superorder **EUCARIDA** Calman, 1904

Order **DECAPODA** Latreille,1802

This order comprises shrimps, crabs, and lobsters. The carapace covers the entire thorax. First 3 pairs of the 8 thoracic limbs are maxillipeds, the first two often bearing the claw or chaela and the eyes stalked. Eggs are borne on the pleopods. The shrimps have developmental stages from eggs, nauplii, protozoeae, mysis, postlarvae and juveniles to adult.

Suborder **DENDROBRANCHIATA** Bate, 1888

Superfamily **SERGESTOIDEA** Dana,1852

Family **LUCIFERIDAE** DeHaan, 1849

Members with short rostrum, shorter than the eye stalk in adults; the body is strongly compressed and there are no gills.

Genus ***Lucifer***

Anterior part of the cephalothorax considerably elongated bearing the long stalked eyes. Body slender and very much transparent. 4th and 5th pereiopods absent. Females loosely carry clusters of eggs on the third pereiopods. Length of eye stalks, spines on the telson; characteristics of petasma and length of the first antennular joint are important characters of identification. Larval forms and adults very common in nearshore waters (Fig. 1. a, b, c & d).

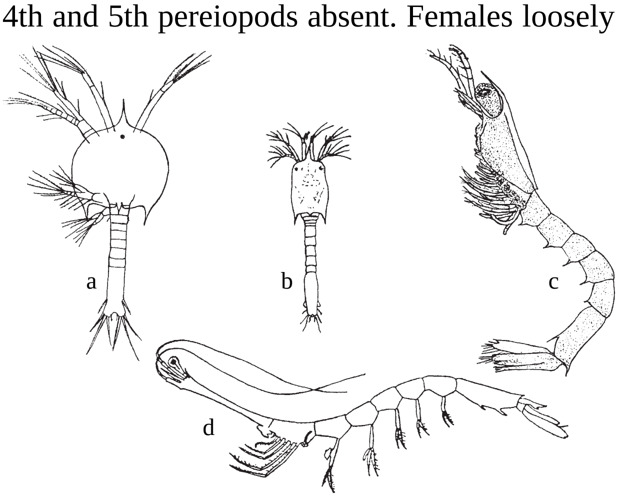



Fig. 1. *Lucifer* (a&b) Protozoeal stages. (c) Mysis stage. (d) Adult. (1.d Wickstead, 1965; Dakin and Colefax, 1940).

**1. *Lucifer hanseni*** Nobili **Female**: Rostrum short and acute. Short eyestalks and the 1st antennular joint slightly longer than the eyes. Length of female 1.2 cm; (Fig. 1. a, b & c).


Fig. 1. *Lucifer hanseni* Nobili (a) Female lateral view (b) Female abdominal Segment showing lateral spine (c) Female terminal part of exopod of uropod. (Dakin and Colefax, 1940).

**Male**: Telson with prominent protruberances on ventral surface. Terminal portion of petasma sheath acute, processus ventralis slender needle with acute end. Length of male 0.9 cm; (Fig. 2. a, b, c, d & e).

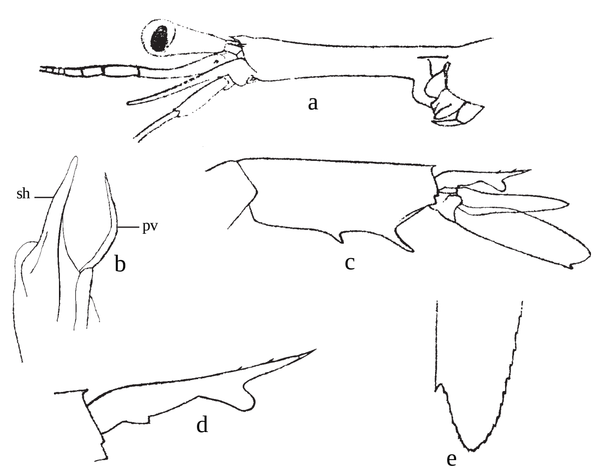



Fig. 2. *Lucifer hanseni* Nobili (a) Male anterior half of cephalothorax lateral view (b) Male terminal portion of petasma inner side view, processus ventralis turned out of the sheath (c) Male sixth abdominal segment, uropods and telson lateral view (d) Male telson lateral view showing ventral protruberance (e) Male terminal part of exopod of uropod. (Hansen, 1919).

Family **SERGESTIDAE** Dana, 1852

The body is moderately compressed and gills are present.

Genus ***Acetes***

**Male**: Lower antennular flagellum and its three basic structures namely, a 2-segmented basal shaft, an inner multi-segmented main branch and the outer clasping spines are the main diagnostic characters including the petasma. **Female**: Coxa-basis of 3rd pereiopod and last thoracic sternum of female are also taken into account for identification purposes. Larvae, juveniles and adults are commonly found in the samples (Figs. 1. a, b & c).

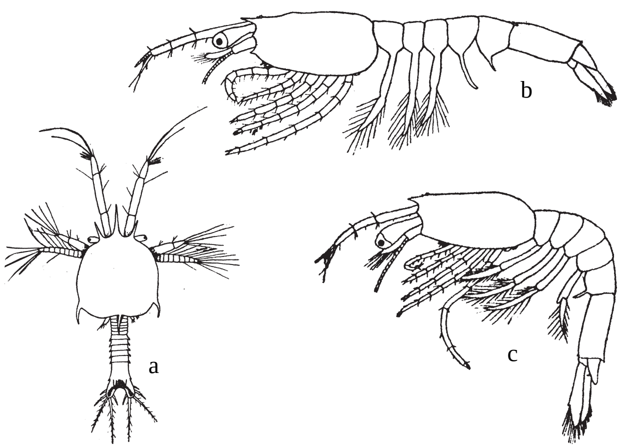



Fig. 1. *Acetes* (a) Protozoeal stage. (b) Post larval stage. (c) Juvenile (Rao, 1968).

**1. *Acetes indicus*** H.Milne Edwards: Large procurved tooth between 1st pair of pleopods present. Basis of 3rd pereiopods with disto-mesial tooth; petasma without coupling folds; 3rd thoracic sternum of **female** with + shaped furrow (Fig. 1. a - e) and (Fig. 2. a - g).

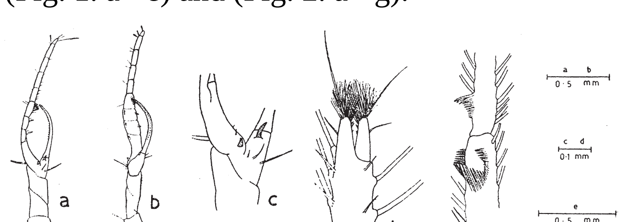



Fig. 1. *Acetes indicus* H. Milne Edwards, (a) Male right lower antenular flagellum dorsal view. (b) Male right lower antennular flagellum outer view. (c) Male basal shaft-main branch-clasping spine junction enlarged. (d) Male chela of 1st pereiopod. (e) Male carpus-propodus of 1st pereiopod showing clasping organ. (Ravindranath, 1980).

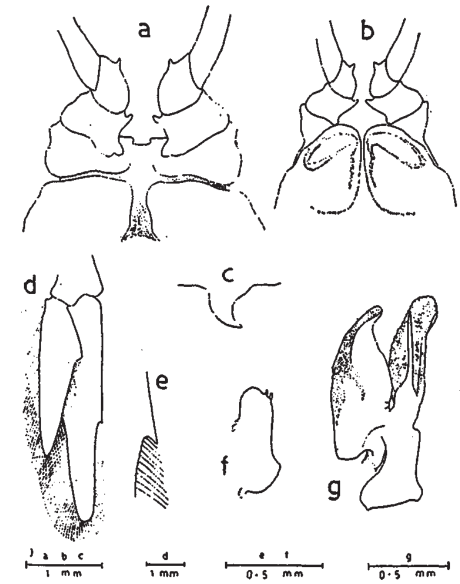



Fig. 2. *Acetes indicus* H. Milne Edwards, (a) Female coxa-basis of 3rd pereiopods and last thoracic sternum. (b) Male coxa-basis of 3rd pereiopods and genital coxae. (c) Male procurved tooth (found between 1st pair of pleopods). (d) Male right uropod. (e) Male marginal tooth of uropodal exopod enlarged. (f) Male appenxit masculina. (g) Male right petasmal half in ventral view. (Ravindranath, 1980).

**2. *Acetes japonicus*** Kishinouye: Apex of telson broadly rounded; 1st segment of the main branch of the lower antennular flagellum of **male** without

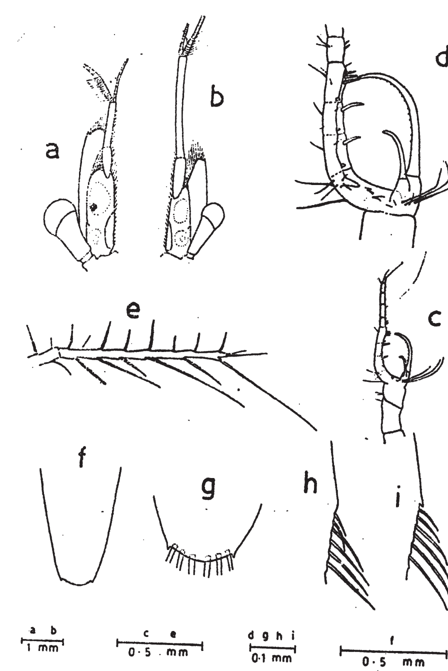



Fig. 1. *Acetes japonicus Kishinouye*. (a) Female left anterior half. (b) Male right anterior half. (c) Male right lower antennular flagellum. (d) Male middle portion enlarged. (e) Male distal segment of 3rd maxilliped. (f) Male distal portion of telson. (g) Male telson tip enlarged. (h) Male uropodal exopod without marginal tooth. (i) Male uropodal exopod with marginal tooth. (Ravindranath, 1980).

any hook-like protruberance; processus ventralis needle-like, originating from the middle of pars media of petasma; 3rd thoracic sternum of female produced posteriorly in the form of a rectangular plate (Fig. 1. a - i.) and (Fig. 2. a - f).

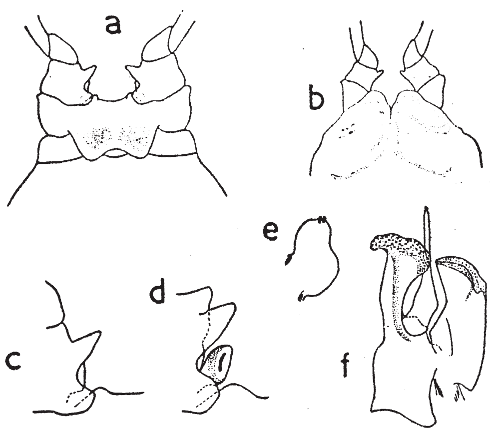



Fig. 2. *Acetes japonicus Kishinouye.* (a) Female coxa-basis ot 3rd pereiopods and last thoracic sternum. (b) Male coxa-basis of 3rd pereiopods and genital coxae. (c & d) Female coxa of right 3rd pereiopod showing genital pore. (e) Male appendix masculina. (f) Male left petasmal half ventral view. (Ravindranath, 1980).

**3. *Acetes erythraeus*** Nobili: Large procurved tooth between 1st pair of pleopods present. Basis of 3rd pereiopods without disto-mesial tooth;

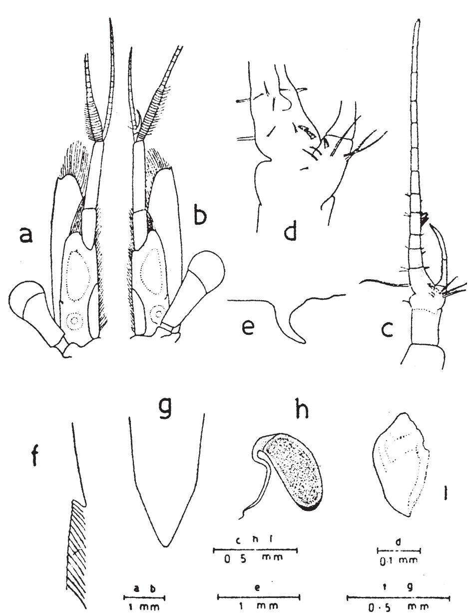



Fig. 1. *Acetes erythraeus* Nobili. (a) Female left anterior half. (b) Male right anterior half. (c) Male right lower antennular flagellum. (d) Male basal shaft-main branch-clasping spine junction enlarged. (e) Male procurved tooth found between 1st pair of pleopods. (f) Male marginal tooth of uropodal exopod. (g) Male telson tip. (h) Male intact spermatophore. (i) Female mass (one half) found below the sternum between 3rd pereiopods in mature individuals. (Ravindranath, 1980).

petasma without coupling folds; 3rd thoracic sternum of **female** plain (Fig. 1. a - i.) and (Fig. 2. a - e).

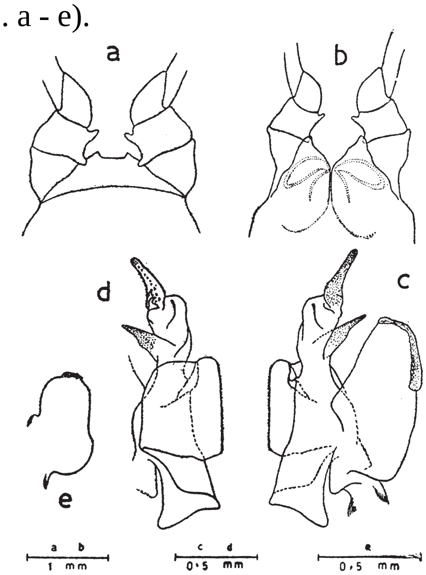



Fig. 2. *Acetes erythraeus* Nobili. (a) Female coxa-basis of 3rd pereiopods and last thoracic sternum. (b) Male coxa-basis of 3rd pereiopods and genital coxae. (c) Male left petasmal half ventral view. (d) Male left petasmal half excluding pars externa dorsal view. (e) Male appendix masculina. (Ravindranath, 1980).

**4. *Acetes sibogae*** Hansen: Large procurved tooth between 1st pair of pleopods absent. Apex of telson obtusely angular (without any teeth); the

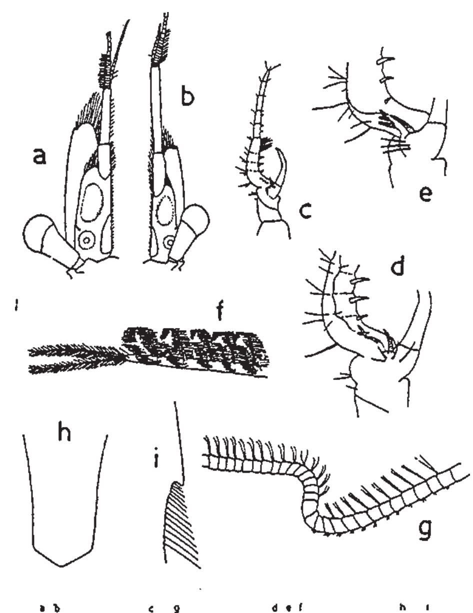



Fig. 1. *Acetes sibogae* Hansen. (a) Female left anterior half. (b) Male right anterior half. (c) Male right lower antennular flagellum. (d&e) Male basal shaft-main branch-clasping spine junction enlarged. (f) Male tip of antennal flagellum showing setation. (g) Male flexture between proximal and distal portions of antennal flagellum. (h) Male distal portion of telson. (i) Male marginal tooth of uropodal exopod. (Ravindranath, 1980).

lower antennular flagellum of **male** with 1 clasping spine; petasma with coupling folds; 3rd thoracic sternum of **female** roughly rectangular and plain (Fig. 1. a – i) and (Fig. 2. a - f).

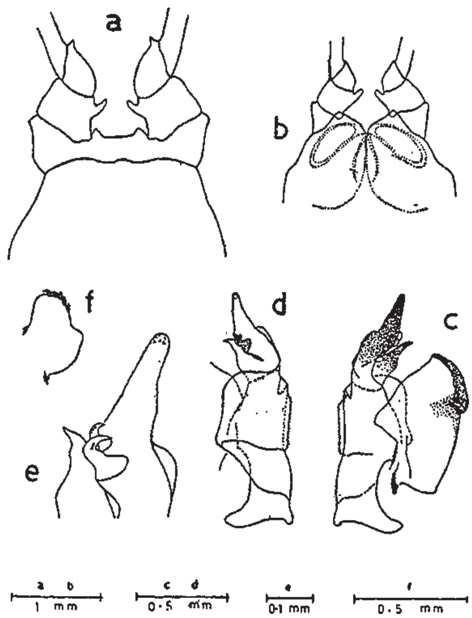



Fig. 2. *Acetes sibogae* Hansen. (a) Female coxa-basis of 3rd pereiopods and last thoracic sternum. (b) Male coxa-basis of 3rd pereiopods and genital coxae. (c) Male left petasmal half ventral view. (d) Male left petasmal half excluding pars externa dorsal view. (e) Male capitulum enlarged dorsal view. (f) Male appendix masculina. (Ravindranath, 1980).

Superfamily **PENAEOIDEA** Rafinesque, 1815

Family **PENAEIDAE** Rafinesque, 1815

Stalked eyes, rostrum elongated, pereiopods 1-3 roughly with equal sized chelae. Telson deeply notched, most species occur over mud or sand bottoms in shallow coastal zones with juveniles entering estuarine areas and mangrove forests.

Genus ***Penaeus***

**Mysis**: In the mysis stage of ***Penaeus***, carapace with prominent supraorbital, pterygostomial and hepatic spines but antennal spine absent. 5th abdominal segment with a pair of posterolateral spines. Dorsomedian spines present on 4th, 5th and 6th abdominal segments, sometimes on 3rd segment also. Uropod with outer margin of exopod produced into a very prominent distolateral spine followed by fringing setae. Telson with 8+8 setae.

**Early postlarvae**: Long and slender. 5th abdominal segment with posterodorsal spine. Telson with 8 pairs of setae.

***1. Penaeus indicus*** H. Milne Edwards: Rostrum long with1 or 2 dorsal spines in the **early postlarvae**; supraorbital, pterygostomial and hepatic spines present on carapace. Posterodorsal spines present on the 4th, 5th and 6th and lateral spines on 5th and 6th abdominal segments. Pleopods well developed. Telson rectangular with 8+8 spines; 3 pairs of lateral and 5 pairs of terminal; median notch absent. Illustrations (CMFRI, 1978) on the postlarva I of ***P. indicus*** taken from the laboratory cultured specimens are shown in Fig. 1: a – j.

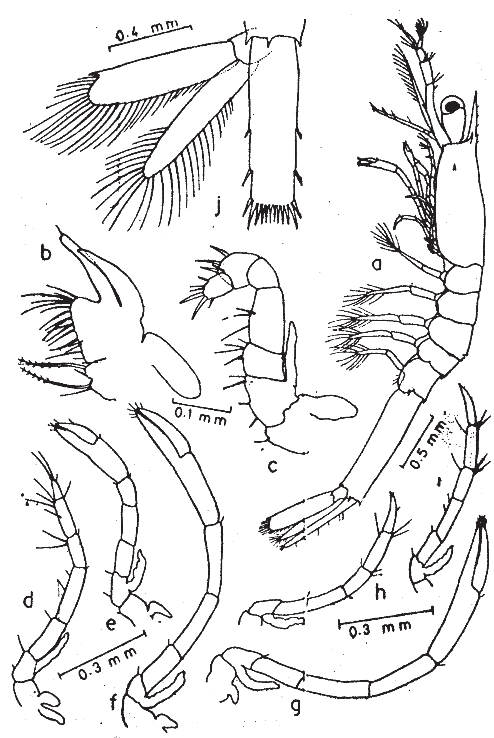



Fig. 1. *Penaeus indicus* H. Milne Edwards. (a) Post larva I lateral view. (b) 1st maxilliped. (c) 2nd maxilliped. (d) 3rd maxilliped. (e) 1st pereiopod. (f) 2nd pereiopod. (g) 3rd pereiopod. (h) 4th pereiopod. (i) 5th pereiopod. (j) Uropod and telson. (CMFRI Bulletin, 1978).

**Juveniles** of ***P.indicus*** were present commonly in the mangrove areas showing the characteristic of double curvature of the rostrum;

dorsal rostral spines were 8 and the ventral rostral spines varied from 5 to 8; the 1st dorsal rostral spine coincided with the 3rd ventral spine distally from the tip.

Genus ***Metapenaeus***

**Mysis**: Carapace without supraorbital spine; antennal spine present, pterygostomial and hepatic spines usually absent in mysis I reappear in later stages. Abdominal segments 5 and 6 only with dorsomedian spines; no lateral spines on any segments. Distolateral spine absent on the outer margin of the exopod of uropod in mysis I appear as very small in subsequent stages. Telson with 7+7 spines.

**Early postlarvae**: Small. rostrum short with 2 dorsal spines and 1 epigastric spine. Hepatic spine present, no supraorbital spine. Posterodorsal spine present only on 6th abdominal segment; no lateral spines on any abdominal segment. Telson with 7 pairs of spines.

**1. *Metapenaeus dobsoni*** (Miers): Rostrum short and blunt with 2-3 dorsal spines. 5th abdominal segment is devoid of posterodorsal spines. Telson with convex posterior end 7+7 spines; 3 pairs lateral and 4 pairs terminal. Illustrations on the postlarva I of ***M.dobsoni*** are given in Fig. 1: a – k and Fig. 2: a – g.

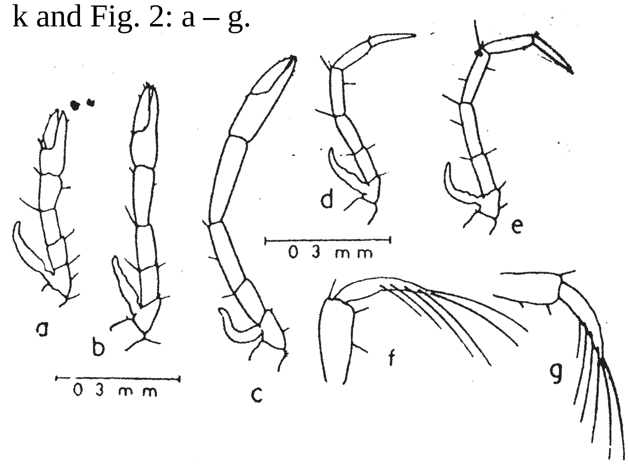



Fig. 2. *Metapenaeus dobsoni* Miers. (a) 1st pereiopod. (b) 2nd pereiopod. (c) 3rd pereiopod. (d) 4th pereiopod. (e) 5th pereiopod. (f) 3rd pleopod. (g) 4th pleopod. (CMFRI Bulletin, 1978).

**2. *Metapenaeus monoceros*** Fabricius: Rostrum short and sharply pointed with 3 dorsal teeth and 1 epigastric tooth. Telson convex posteriorly bears 7+7 spines; 3 pairs of lateral and 4 pairs of terminal spines. Illustrations on the postlarva I of ***M. monoceros*** are given in Fig. 1: a – m.

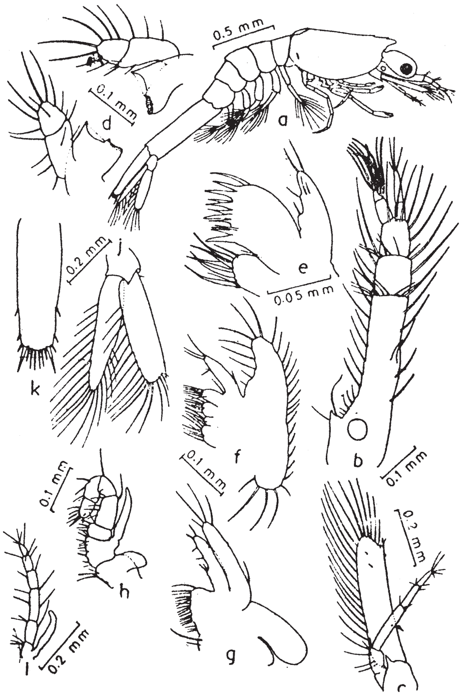



Fig. 1. *Metapenaeus dobsoni* Miers. (a) Post larva I lateral view. (b) Antennule. (c) Antenna. (d) Mandible. (e) Maxillule. (f) Maxilla. (g) 1st maxilliped. (h) 2nd maxilliped. (i) 3rd maxilliped. (j) Uropod. (k) Telson. (CMFRI Bulletin, 1978).


Fig. 1. *Metapenaeus monoceros* Fabricius (a) Post larva 1 lateral view. (b) Antennule. (c) Maxillule. (d) 1st maxilliped. (e) 2nd maxilliped. (f) 1st pereiopod. (g) 2nd pereiopod. (h) 3rd pereiopod. (i) 5th pereiopod. (j) Pleopod II. (k) Uropod. (l) Distolateral tip of the exopod or uropod. (m) Telson. (CMFRI Bulletin, 1978).

Chromatophore pattern on the tail fan has been found to be a reliable and easily observed criterion for the identification of postlarval penaeids from the brackishwater regions (CMFRI,1978). The distinguishing characters of the postlarvae of ***Penaeus indicus, Metapenaeus dobsoni*** and ***M.monoceros*** are illustrated. In ***P. indicus*** telson bears chromatophores in distal half only (Fig. 1. a – d); in ***M. dobsoni*** a prominent chromatophore is present in the middle of each uropod ramus (Fig. 2. a-d).and in ***M.monoceros*** the chromatophores are present on inner rami of uropods while outer rami remain colourless; (Fig. 3. a-d).

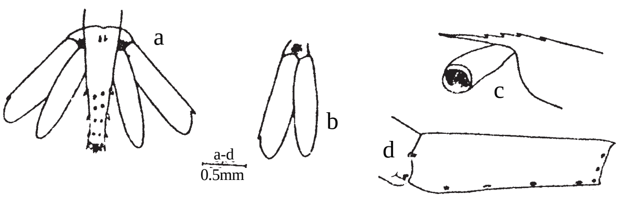



Fig. 1. *Penaeus indicus* (C. L. 1.70 mm) (a) Tail fan. (b) Left uropod. (c) Anterior end of carapace. (d) 6th abdominal segment. (CMFRI Bulletin, 1978).

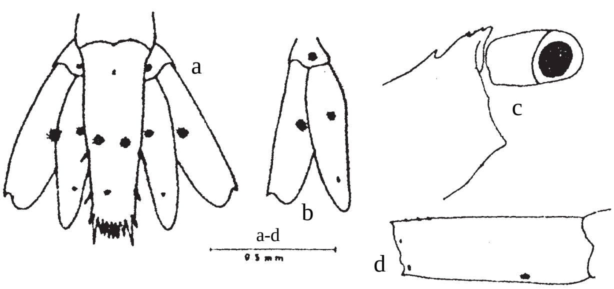



Fig. 2. *Metapenaeus dobsoni* (C. L. 0.89 mm) (a) Tail fan. (b) Left uropod. (c) Anterior end of carapace. (d) 6th abdominal segment. (CMFRI Bulletin, 1978).

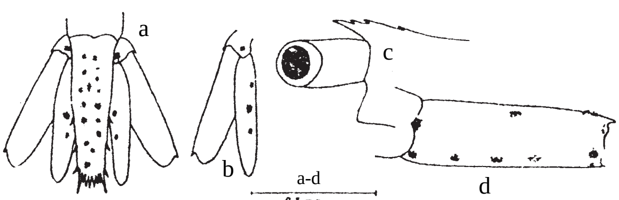



Fig. 3. *M.monoceros* (C. L. 1.0 mm) (a) Tail fan. (b) Left uropod. (c) Anterior end of carapace. (d) 6th abdominal segment. (CMFRI Bulletin, 1978).

Suborder **PLEOCYEMATA** Burkenroad, 1963

Infraorder **ANOMURA** MacLeay, 1838

Superfamily **PAGUROIDEA** Latreille, 1802

Family **DIOGENIDAE** Ortman, 1892

**HERMIT CRABS**: Most hermit crabs occupy spiraled gastropod shells that protect the soft, elongated and twisted abdomen. Inhabitants of mainly shorelines but occur from land to deep sea. Illustrations on the external morphology, appendages and reproduction in decapod crabs are given in Fig. 1.

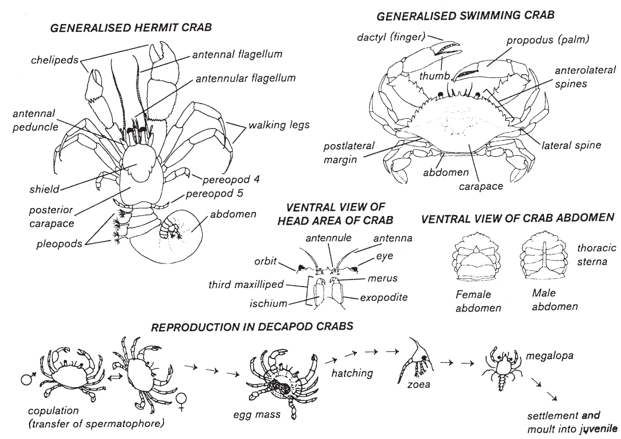



Fig. 1. External morphology, appendages and reproduction in decapod crabs. (Richmond, 1997)

***Clibanarius padavensis*** De Man and ***Diogenes avarus*** Heller are very common in the Indian mangroves.

**Genus** ***Clibanarius***

***1. Clibanarius padavensis*** De Man: **Zoeal stages**: Smooth carapace, rostrum broad and blunt reaching beyond the antennule and antennae. Antennal scale without a terminal spine and abdominal segments are smooth. **Telson**: Broad and triangular with a deep notch on the posterior margin, notch fringed with fine hairs; 1st process generally blunt, fingerlike and situated slightly laterally, 4th telson process reduced to a

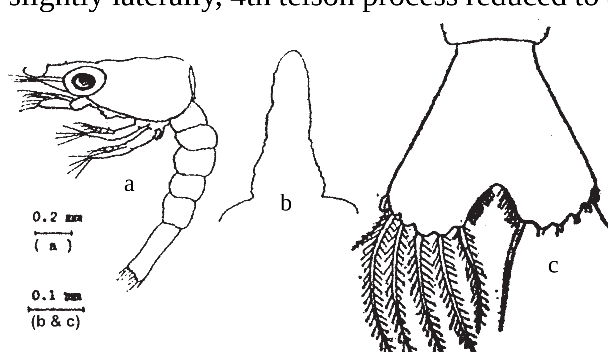



Fig. 1. *Clibanarius padavensis* De Man 1st zoea, carapace length - 0.9 mm; abdomen length - 1.2 mm (a) Entire larva lateral view (b) Rostrum dorsal view. (c) Telson. (Shenoy and Sankolli, 1975).

tubercle in stage 3. Process formula not more than 8+1+8 (Fig. 1: a, b & c; 2: a & b; 3: a & b; 4: a & b).

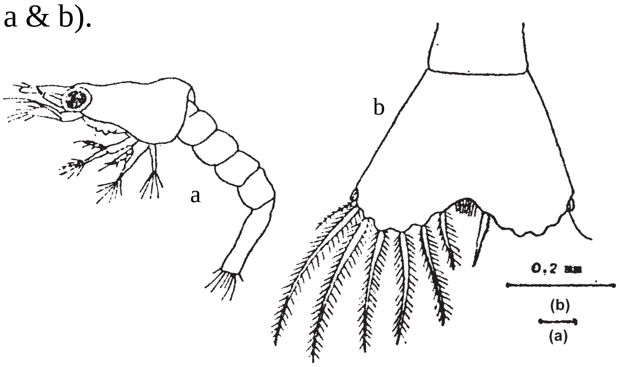



Fig. 2. *Clibanarius padavensis* De Man 2nd zoea, carapace length - 0.9 mm; abdomen length - 1.2 mm (a) Entire larva lateral view (b) Telson. (Shenoy and Sankolli, 1975).

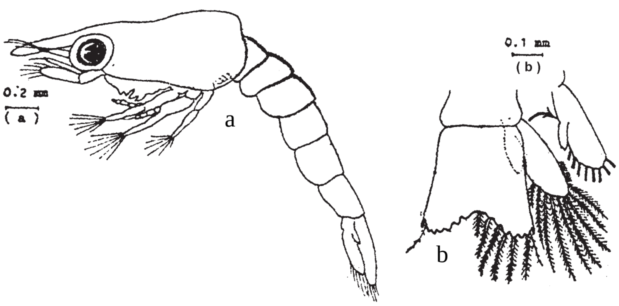



Fig. 3. *Clibanarius padavensis* De Man 3rd zoea, carapace length - 0.9 mm; abdomen length - 1.2 mm (a) Entire larva lateral view (b) Telson and uropod. (Shenoy and Sankolli, 1975).

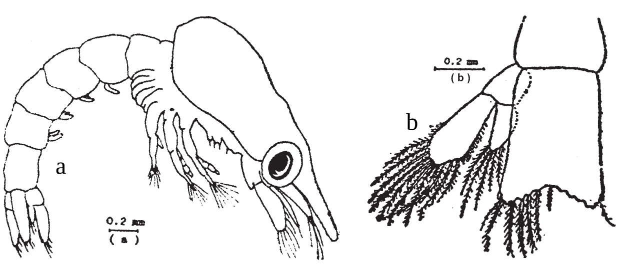



Fig. 4. *Clibanarius padavensis* De Man 4th zoea, carapace length - 0.9 mm; abdomen length - 1.2 mm (a) Entire larva lateral view. (b) Telson and uropod. (Shenoy and Sankolli, 1975).

**Glaucothoe**: Symmetrical with ocular scales; chelipeds subequal, all the segments smooth; fingers hoofed. **Telson**: Posterior margin with not more than 9 setae (Fig. 5: a & b).

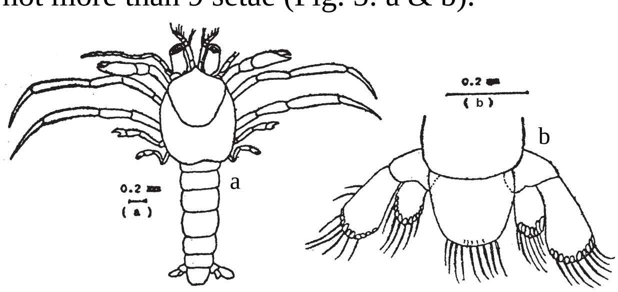



Fig. 5. *Clibanarius padavensis* De Man Glaucothoe. (a) Entire larva dorsal view. (b) Telson and uropods. (Shenoy and Sankolli, 1975).

Genus ***Diogenes***

***2. Diogenes avarus*** Heller: **Zoeal stages**: Eyes sessile and large. Rostrum smooth, pointed reaching well beyond antennule and antenna. Carapace smooth, posterolateral angles rounded. **Telson**: Triangular, broad, posterior margin almost straight with a small median notch. Process formula 7 + 7, 1st a small, sharp spine; 2nd an anomuran hair; 3rd to 7th long plumose setae, 5th process being the longest throughout the zoeal stages. No anal spine. Median notch of posterior margin disappears in later zoeal stages. 5th process continues to be the longest. 4th zoeal stage distinguished by large carapace almost covering the middle of 3rd abdominal segment, segmented uropods. (Fig. 1: a, b & c; 2: a; 3: a & b; 4: a & b).

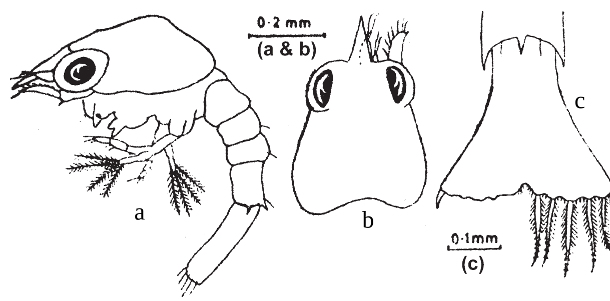



Fig. 1. *Diogenes avarus* Heller 1st zoea (a) Entire larva lateral view (b) Carapace anterior part with rostrum. (c) Telson. (Sankolli and Shenoy, 1975).

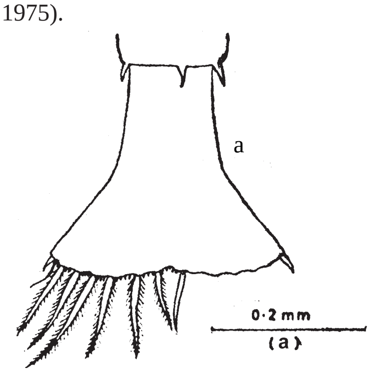



Fig. 2. *Diogenes avarus* Heller 2nd zoea (a) Telson. (Sankolli and Shenoy, 1975).

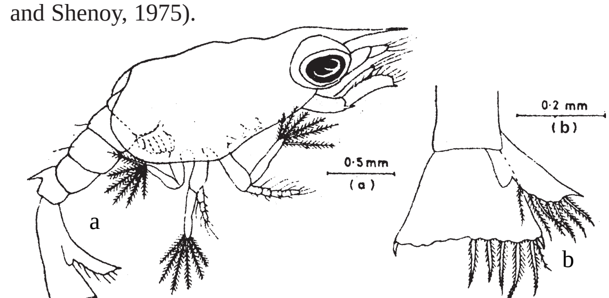



Fig. 3. *Diogenes avarus* Heller 3rd zoea (a) Entire larva lateral view (b) Telson and uropod. (Sankolli and Shenoy, 1975).

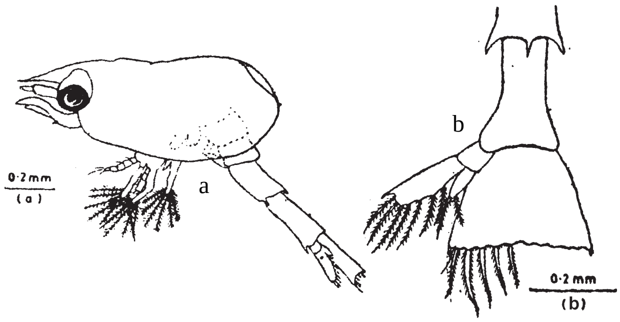



Fig. 4. *Diogenes avarus* Heller 4th zoea (a) Entire larva lateral view (b) Telson and uropod. (Sankolli and Shenoy, 1975).

**Glaucothoe**: Carapace well developed with cervical groove; rostrum much reduced, rostral scale well developed. Eye stalks long, reaching the last segment of antennular peduncle. Ocular scales serrated distally as in adult (Fig. 5: a, b & c). I **crab instar** (Fig. 6: a, b & c).

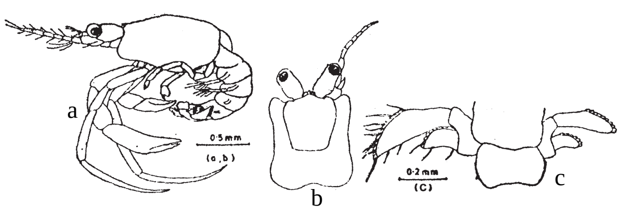



Fig. 5. *Diogenes avarus* Heller Glaucothoe (a) Entire larva lateral view (b) Carapace - anterior part with rostrum. (c) Telson and uropods. (Sankolli and Shenoy, 1975).

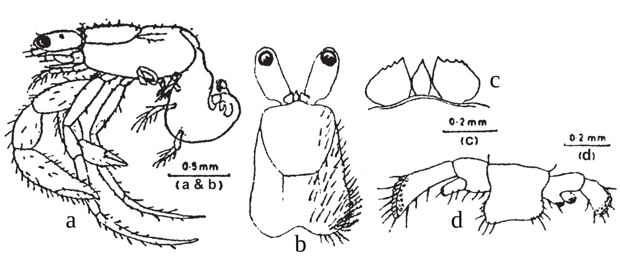



Fig. 6. *Diogenes avarus* Heller 1st crab instar (a) Entire larva lateral view. (b) Carapace - anterior part with rostrum, dorsal view. (c) Carapace - tip. (d) Telson and uropods. (Sankolli and Shenoy, 1975).

Infraorder **BRACHYURA** Latreille, 1802

Section **EUBRACHYURA** de Saint Laurent, 1980

Subsection **HETEROTREMATA** Guinot, 1977

Superfamily **PORTUNOIDEA** Rafinesque, 1815

**TRUE CRABS**: A large and diverse group in which the carapace is generally dorsoventrally flattened with a defined margin and fused with the ventral plate of the exoskeleton anterior to the mouth, antennae short, the 1st and often the 2nd pair of pereiopods are chaelate, the abdomen reduced and folded under the carapace, typically a wide carapace, with 4-9 anterolateral teeth, paddle like dactyl. (Fig.1. under hermit crab).

Family **PORTUNIDAE** Rafinesque, 1815

Genus ***Scylla***

**1. *Scylla serrata*** (Forskal ): The mangrove or mud crab, carapace width 220 mm, length 140 mm. Carapace with 9 distinctive sharp anterolateral spines of nearly equal size. Cheliped unequal and large with 3 spines on the anterior border. Found in shallow coastal waters with soft substrates, enter mangroves to moult and mate, release eggs in open water. The dorsal spine is bent backwards, lateral spines are closely pressed against the sides of the body, rostral spine is bent over the mouth region in the first zoeal stage. (Fig. 1: a, b & c).

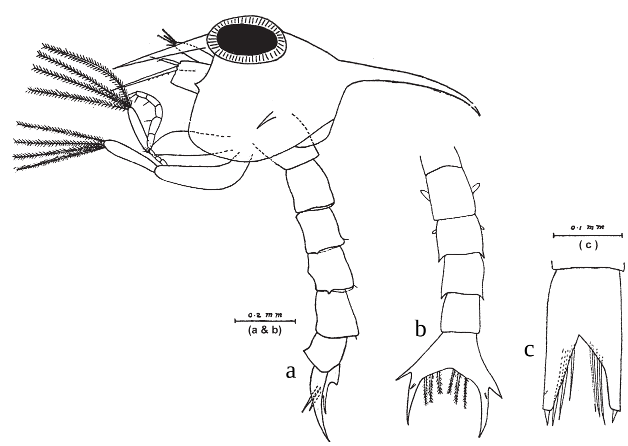



Fig. 1. *Scylla serrata* Forskal (a) Late 1st zoea. (b) Abdomen of the late 1st zoea. (c) Telson of the early 1st zoea. (Naidu, 1965).

Genus ***Thalamita***

**2. *Thalamita crenata*** Milne-Edwards: Larval stages in portunidae are very much similar creating the process of identification difficult. Hence minor differences are taken into account while differentiating them. **Zoeal** stages from 1 to 5 can be separated from one another by counting the number of natatory setae on the 1st and 2nd maxillipeds – 4, 6, 8, 10 & 12 setae respectively (Fig. 1: a – i). **Megalopa** also by the number of setation: on the pleopods – 20, 19, 18; on the peduncle of antennules – 5, 4, 2; on the flagellum of the antenna - 0, 0, 3, 2, 4, 2, 3, 2; and on the basal endopodite of maxillule – 20. Crab instar setation of the peduncle of the antennae – 10, 4, 2,; basal endite of maxillule – 19; exopodite of the maxilliped 1:37; endopodite of maxilliped 3:48, 20, 17, 10 and 9 setae.

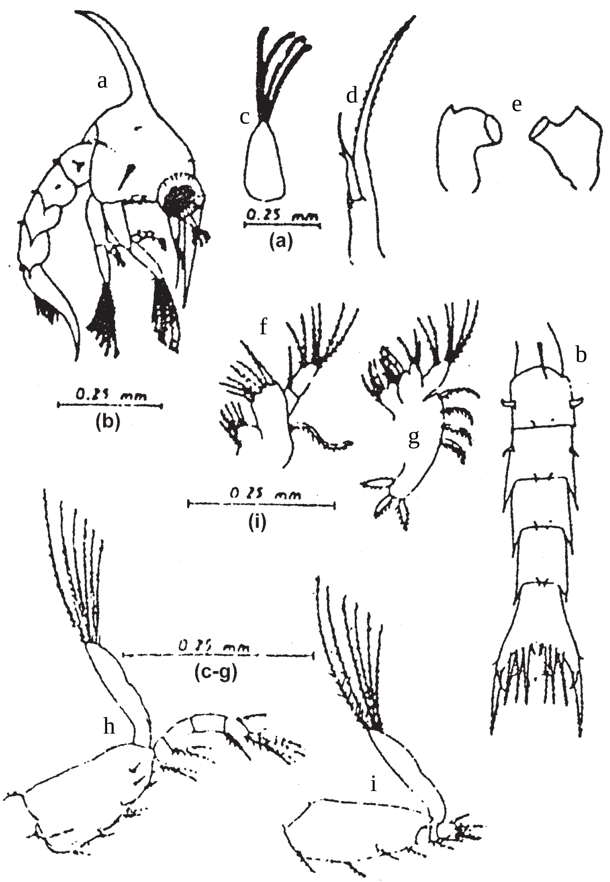



Fig. 1. *Thalamita crenata* Milne-Edwards (a) 2nd zoea lateral view. (b) Abdomen and telson. (c) Antennule. (d) Antenna. (e) Mandibles. (f) Maxillule. (g) Maxilla. (h) 1st maxilliped. (i) 2nd maxilliped. (Krishnan and Kanupandi, 1990).

Superfamily **GRAPSOIDEA** MacLeay, 1838

Family **SESARMIDAE** Dana, 1851

Genus ***Sesarma***

**1. *Sesarma lanatum*** Alcock: Zoea: Rostral spine 0.20 – 2.46 mm; dorsal spine 0.16 – 0.32 mm; carapace length 0.30 – 0.69 mm; and abdomen length 0.79 – 1.37 mm. **Telson**: Widely forked with a shallow median notch on posterior margin when compared with other species; cornua with 2 rows of spinules; process formula 3+3 (Fig.1: a-i).

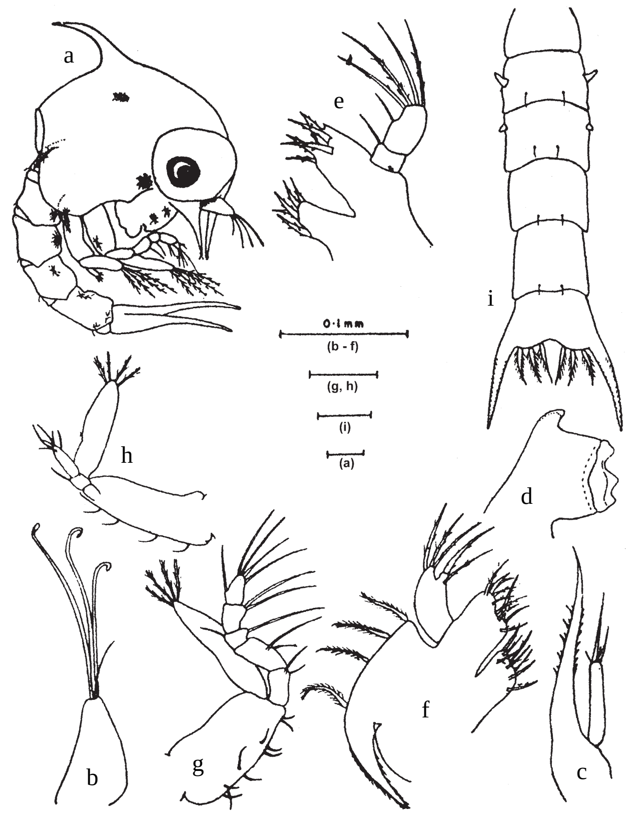



Fig. 1. *Sesarma lanatum* Alcock - 1st zoea (a) Lateral view. (b) Antennule. (c) Antenna. (d) Mandible. (e) 1st maxilla. (f) 2nd maxilla. (g) 1st maxilliped. (h) 2nd maxilliped. (i) Abdomen. (Kakati and Sankolli, 1975).

**Megalopa**: Carapace smooth with 2 pairs of dorsal humps; frontal region broad and rostrum directed downwards; eyes large. **Telson**: posterior margin smooth without any setae or spines (Fig. 2: a – l). 1st zoea of **S. *lanatum*** differs from the others in the following: a) Antennal exopod with 2 unequal and 2 minute setae as against only 2 setae in the remaining species. b) All abdominal segments smooth except for lateral knobs and dorsal setae unlike in other species. c) **Telson** is more widely forked than in others with a shallower median notch. In megalopa the telson is characteristic with a smooth posterior margin devoid of spines or setae.

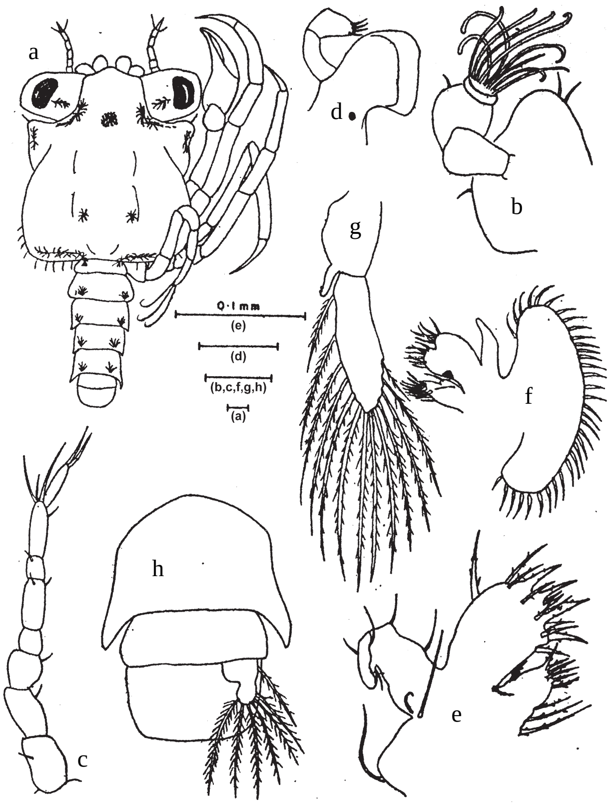



Fig. 2. *Sesarma lanatum* Alcock - Megalopa (a) Dorsal view. (b) Antennule. (c) Antenna. (d) Mandible. (e) 1st maxilla. (f) 2nd maxilla. (g) 1st pleopod. (h) Telson and uropod. (Kakati and Sankolli, 1975).

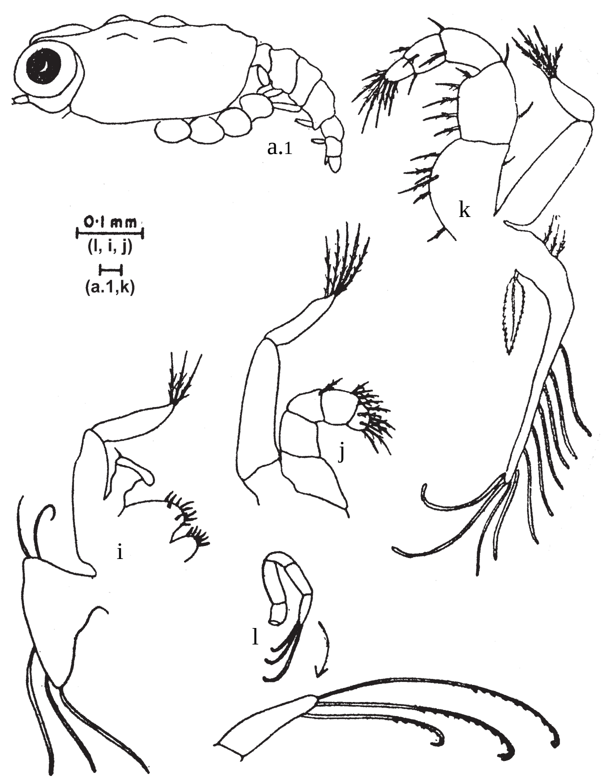



Fig. 2. *Sesarma lanatum* Alcock - Megalopa (a.1) Lateral view. (i) 1st maxilliped. (j) 2nd maxilliped. (k) 3rd maxilliped. (l) 5th pereiopod bud (enlarged view is also given). (Kakati and Sankolli, 1975).

## Phylum **CHAETOGNATHA**

Chaetognatha or arrow worms are fast swimmers and voracious predators. Elongated torpedo - like shape, transparent and the head with two eyes, mouth surrounded by chitinous spines, paired lateral fins and an expanded terminal caudal fin. Identification is usually based on teeth, ovaries and seminal vesicles.

### Genus ***Sagitta***

**1. *Sagitta enflata*** Grassi: Origin of anterior fin almost midway between neck and tip of tail, seminal vesicles touching tail fin, anterior teeth 4 to 8; posterior teeth 4 to 13. Ovaries not surpassing origin of anterior fins. It is transparent. Specific character is the anterior fin and the situation of the broadest part of the caudal fin. Reaches 20mm in length mostly between 5 and 10 mm; (Fig.1: a, b, c & d).

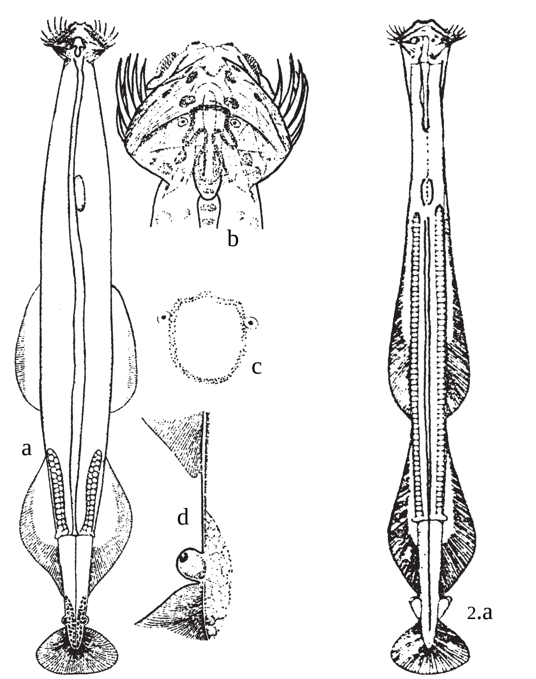



Fig. 1. *Sagitta enflata* Grassi (a) Entire animal dorsal view. (b) Head dorsal view. (c) Simple corona ciliata. (d) seminal vesicle, ventral view.

Fig. 2. *Sagitta bedoti* Beraneck (a) Entire animal dorsal view. (Dakin and Colefax, 1940).

**2. *S. bedoti*** Beraneck: Intestinal diverticula absent, collarette short, restricted to neck region. Ova arranged in 3 rows. Length 12-14 mm; (Fig. 2: a).

Phylum **CTENOPHORA**

Class **TENTACULATA**

Order **CYDIPPIDA**

Family **PLEUROBRACHIIDAE**

Egg-shaped, 2 cm long. Characteristic feature is the equally spaced 8 longitudinal rows of ciliary plates called comb plates beating successively. Two branched, sticky tentacles, retractile into pockets. Sense organs at one end of body, mouth at the other. Highly transparent.

Genus ***Pleurobrachia***

**1. *Pleurobrachia globosa*:** (Fig. 1.a)

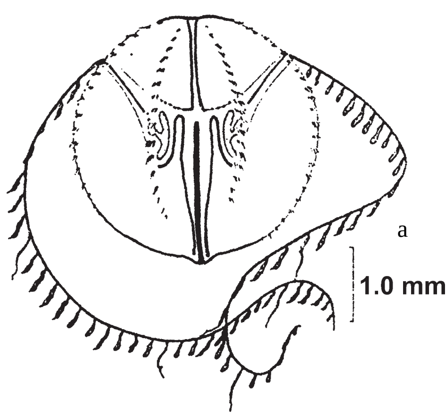



Fig. 1. *Pleurobrachia globosa* (a) Entire animal dorsal view. (Reymont, 1983).

Phylum **ANNELIDA**

Class **POLYCHAETA**

The word polychaeta means many bristles, as the popular name bristle worm suggests. The class includes over 8,000 species of segmented, mostly marine worms belonging to the phylum Annelida. Some species are free swimming. The crawling polychaetes are found among weeds or under stones. Vast populations are burrowing forms on sandy beaches and muddy estuaries, especially in mangroves while others inhabit tubes in sand or encrusted onto stones or rock. Whether the polychaete is free moving (errant) or immobile (sedentary) the body consists of a head bearing paired sensory (antennae) and feeding (palps) appendages followed by a series of bilaterally symmetrical segments. Each segment typically bears a pair of parapodia, the feet like lateral projections usually consisting of bristles or chaetae or setae. Identification can be achieved by examining the basic features of the head, parapodium and chaetae. Illustrations of external morphology and appendages of 4 families of Nereidae, Eunicidae, Terebellidae and Sabellidae are given in Fig.1: a, b, c and d. Cross-sections of parapodia of families Phyllodocidae, Nereididae and Eunicidae in Fig.2: a, b & c. Examples of different types of polychaete chaete are also shown in Fig. 3.a. The larvae of polychaeta are usually planktonic (Fig. 4: a & b).

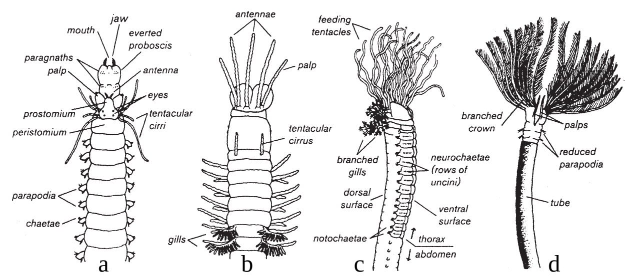



Fig. 1. External morphology and appendages of families. (a) Nereidae dorsal view. (b) Eunicidae dorsal view. (c) Terebellidae lateral view. (d) Sabellidae ventral view. (Richmond, 1997)

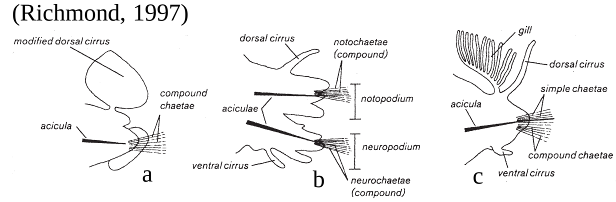



Fig. 2. Diagramatic representations of cross-sections of parapodia of families. (a) Phyllodocidae. (b) Nereididae. (c) Eunicidae. (Richmond, 1997).

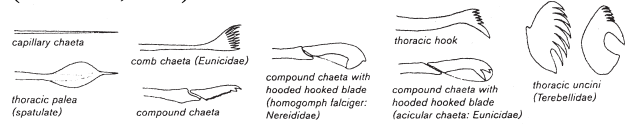



Fig. 3.a. Different types of polychaete chaetae. (Richmond, 1997).

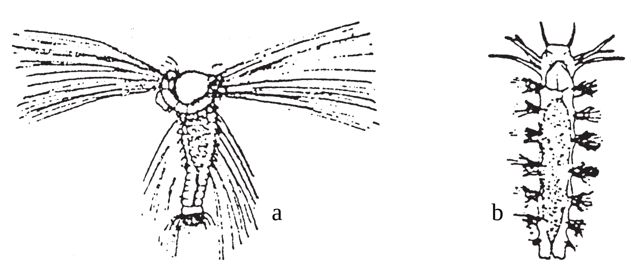



Fig. 4. (a) Spionid larva. (b) Nereid larva. (Wickstead, 1965).

Family **EUNICIDAE**

Genus ***Marphysa***

**1. *Marphysa mossambica*** (Peters): The most common polychaetes of the mangrove ecosystem are those of Eunicidae and Nereidae. ***M. mossambica*** is a typical resident of the mangrove system. Head strongly bilobed; 3 smooth antennae and 2 slender lateral palps, slightly longer than the head, with several annular rings at base. Eyes small. No tentacular cirri. Colour usually dark green with red and black tints. Length 30 to 50 cm; (Fig. 1: a & b).

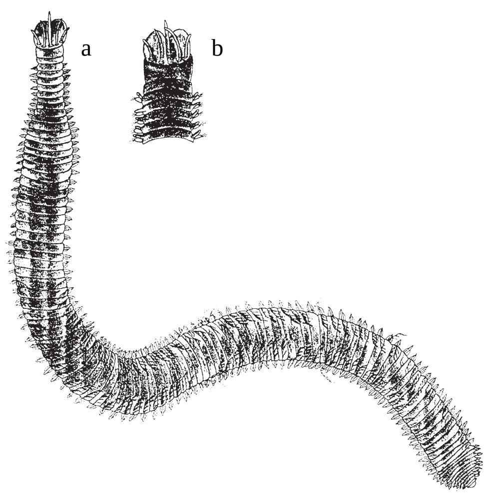



Fig. 1. *Marphysa mossambica* Peters (a) Whole animal dorsal view. (b) Anterior portion. (Richmond, 1997).

Phylum **MOLLUSCA**

Class **PELECYPODA (=BIVALVIA, LAMELLIBRANCHIA)**

Order **VENEROIDA**

Family **VENERIDAE**

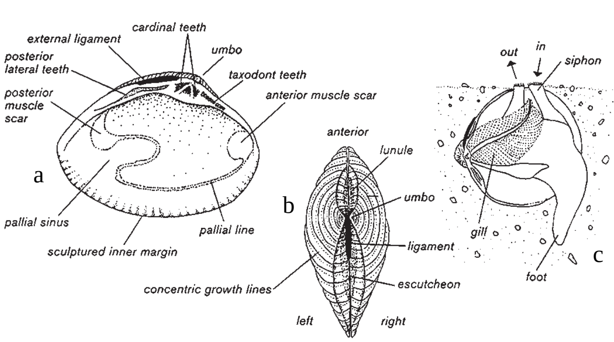



Fig. 1. External characters and morphology of bivalves (a) Inner view. (b) Anterio-posterior view. (c) Section through burrowing bivalve. (Richmond, 1997).

Illustrations on the morphology and external characters of the bivalves are given in Fig. 1: a, b & c).

**1. *Meretrix meretrix*** (Linnaeus): Shell thick, moderately inflated with a variable shape, nearly equilateral or inequilateral; trigonal-ovate in outline. Umbones anterior, poorly inflated. Anterior and ventral margins broadly rounded, posterior end of shell bluntly angled. Lunule smooth and poorly defined. Outer surface of shell smooth, except from low concentric growth marks. Periostracum smooth and glossy. Hinge plate thick, bearing in each valve 3 cardinal teeth and well developed anterior lateral teeth: a strong one in left valve and 2 smaller ones in right right valve. Pallial sinus broad and rather shallow. **Colour**: variable in colour and pattern; interior white fawn to chestnut brown or dark brown along posterodorsal margin. Size: Shell length 6 to 7 cm; (Fig. 1: a & b).

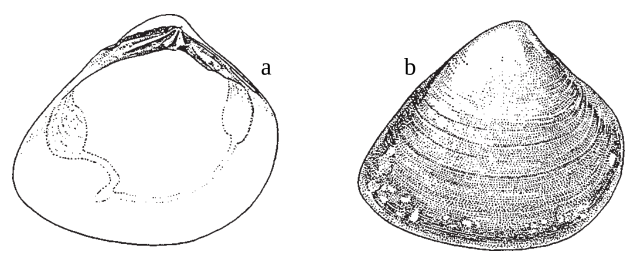



Fig. 1. *Meretrix meretrix* (Linnaeus). (a) Interior of left valve (b) Exterior of right valve. (FAO, 1998).

**2. *Paphia malabarica*** (Chemnitz): The shell is triangularly ovate with moderately inflated valves; smooth or with weak concentric grooves. Thickness moderate. The anterior and posterior margins are narrow and rounded. Shell is shorter and very deeply sculptured with strong close-set concentric ridges which are raised and rounded and not flattened. The separate interstitial grooves are also much deeper. The concentric ridges and grooves are strictly parallel to the margin of the shell. The inner surface of the shell is quite smooth throughout and its margin not diverticulated. Hinge bears 3 short, thick cardinal teeth, the tooth in front of the cardinals in the left valve and the hollow in the right valve are rudimentary. Pallial sinus is moderately deep and

U-shaped. Lunule flattened, narrow and greatly elongated. **Colour**: shell pale yellowish-brown, indistinctly rayed with grayish brown bands; sometimes the surface is elaborately mottled with brownish-angular markings all over (Fig. 2:a).


Fig. 2. *Paphia malabarica* (Chemnitz). (a) External morphology. (Sathyamurthi, 1956).

The larval forms of clams that occur in the collections are mostly veliger stages and cannot be traced to the generic level because of the similarity in appearance (Fig. 3: a, b & c). These are usually found in the mangrove ecosystem.

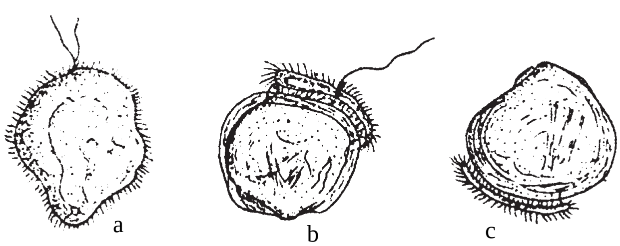



Fig. 3. General pattern of life cycle of clams (a) Trochophore (b) Veliger (c) Spat. (CMFRI).

3. ***Sunetta scripta*** Venus shell or Carpet shell (Linnaeus) : The spat exhibit almost adult characters. Shells solid, thick and equivalve. Ovate in shape with gloosy surface. Umbo more or less rounded. Colour straw yellow or creamy with brown coloured streaks. Cardinal teeth well developed. Two conspicuous muscle scars. Pallial sinus present. Inside shell margin serrated. Habitiat : sandy shores in shallow water.

*Sunetta scripta*

Order **MYTILOIDA**

Superfamily **MYTILACEAE**

Family **MYTILIDAE**

**1. *Perna viridis*** (Linnaeus): Shell elongate, roughly trigonal-ovate in outline, swollen and pointed anteriorly, rounded and compressed posteriorly. Umbones terminal and sharply tapering. Anterior margin reduced. Ventral margin long and often somewhat concave. Outer surface nearly smooth apart from concentric growth marks and faint radial lines. Periostracum thick and smooth. Hinge with 1 small tooth in right valve and 2 in the left. Anterior adductor

Fig. 1. *Perna viridis* (Linnaeus). (FAO, 1998).

scar absent in adults. Posterior retractor scars large confluent with the posterior adductor scar. Anterior retractor scar separated, elongate-ovate in shape. Internal margins smooth. **Colour:** outside whitish under a bright periostracum which is dark brownish green anteriorly and olive-green to bright green posteriorly. Interior an iridescent pale bluish green with a vivid green margin of periostracum. Size: Shell length 4 to 6.5 cm (Fig. 1).

The spat and plantigrades of this species are encountered in the samples (Fig. 2: a).

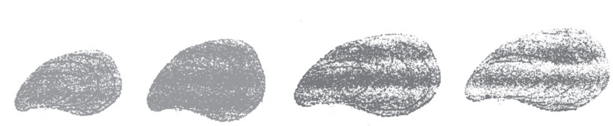


Fig. 2. (a) The Spat and plantigrades of *Perna viridis* (Linnaeus). (CMFRI).

Order **ARCOIDA**

Family **ARCIDAE**

**1.** ***Villorita cyprinoides*** (Gray): Shelll thick, ovate-triangular with strong concentric ridges which are more strongly developed in anterior half. Umbones prominent and well elevated. Hinge margin short and thick, always with 3 oblique cardinal teeth of which anterior in right valve and posterior in left valve obsolete. Pallial sinus small. Lunule narrow and ligament large. **Colour**: Periostracum dark olive brown to blackish brown (Fig. 1: a).

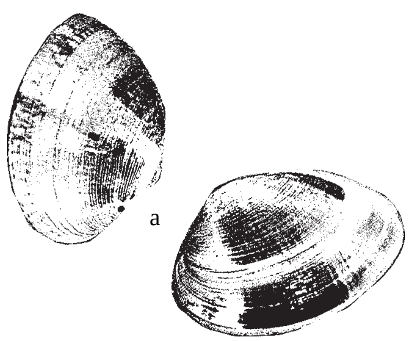



Fig. 1. (a) *Villorita cyprinoides* (Gray). (Sathyamurthi, 1956).

Class **GASTROPODA**

Illustrations on the morphology and external characters of the gastropods are given in Fig.1: a.

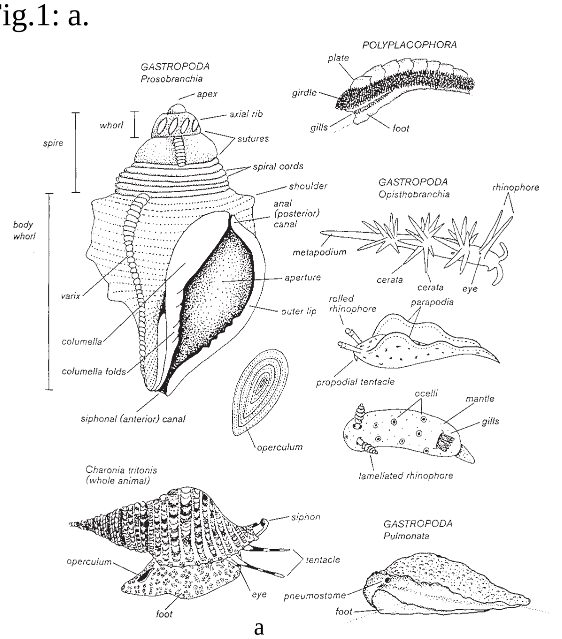



Fig. 1. (a) External morphology of gastropods. (Richmond, 1997).

Order **MESOGASTROPODA**

Family **POTAMIDIDAE**

***1. Telescopium (T) telescopium*** (Linnaeus): Shell large with a high conical spire and a broad rather flat base. Axial sculpture reduced to growth marks. Spire whorls flat sided with weak sutures. 3 large spiral cords and a narrow one alternate with deep spiral grooves. Spiral cords may disappear with age and erosion. Body whorl angulate to strongly rounded on periphery. Aperture obliquely quadrangular and small. Columella twisted with a strong central spiral ridge. Anterior siphonal canal very short, open and strongly twited. **Colour**: outside dark reddish brown to almost black, often with a paler spiral band near the suture. Interior similarly coloured with a light brown or whitish columella. Size: Shell length 5 to 8 cm (Fig. 1: a).

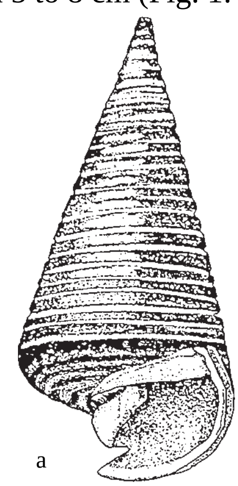



Fig. 1. (a) *Telescopium (T) telescopium* (Linnaeus): Ventral view (FAO, 1998).

**2.** ***Cerithidea obtusa*** (Lamarck): Shell medium size with a moderately high conical spire and broad rounded base. Spire whorls convex with a moderately deep suture. 6 or 7 rounded spiral cords crossed by stronger, broad axial ridges forming a pattern of more or less sharp nodules. Body whorl wide, rounded at the periphery with axial ridges fading and with 12 to 15 fine spiral cords on the base. Apical part of the spire often gets broken. Aperture wide, subcircular in outline, without a wing-like expansion at posterior end. Outer lip thickened and flared with a tongue-shaped anterior end produced over the siphonal canal. Columella narrow, posteriorly interrupted without internal spiral ridges. Anterior siphonal canal short, open and oblique. **Colour**: outside shell brown or dull purplish brown, with a brighter zone just below the suture; base plain brown or yellowish dark brown. Size: Shell length 5 to 6 cm; Fig. 2: a).

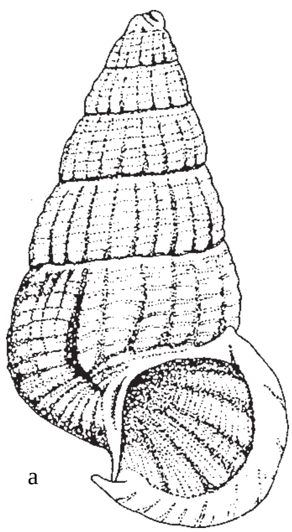



Fig. 2. (a) *Cerithidea obtusa* (Lamarck): Ventral view. (FAO, 1998).

Common in mangrove swamps, on roots and branches above the substrate or on mud tidal banks.

Order **MYOIDEA**

Family **TEREDINIDAE**

Subfamily **BANKIINAE**

Genus ***Nausitoria***

The generic classification of the teredinidae is based on the morphology of soft parts in conjunction with the type of pallets. The pallets are the unique structures located at the base of the siphons to close the burrow when the siphons are withdrawn. The characters of the shell can be useful in a few species but only in conjunction with the pallets because the shells of species belonging to different genera are very similar.

**1. *Nausitoria hedleyi*** Schepman: Pallets long, feather-like and stalk cylindrical, stout and much shorter than the blade. Outer surface of blade convex, and inner surface flat. The blade is composed of compactly packed segments. Shell large sub-globular with large anterior slope. (Fig. 1: a, b, c & d).

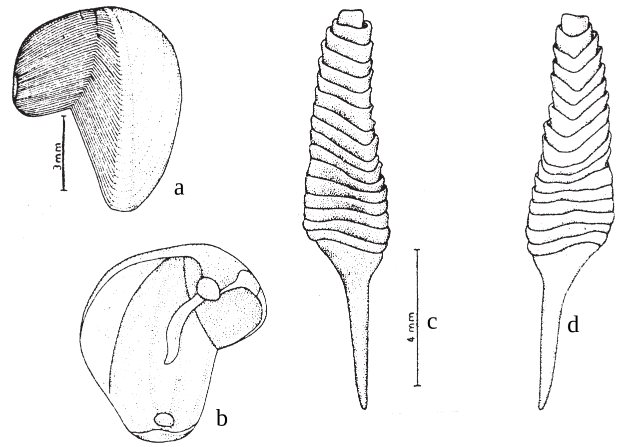



Fig. 1. *Nausitoria hedleyi* Schepman. (a) Outer view of shell. (b) Inner view of shell. (c) Outer view of pallet. (d) Inner view of pallet. (Nair and Salim, 1994).

The genus occurs chiefly in brackish waters and mangrove swamps of tropical and subtropical waters. Most destructive species of shipworms in the brackish water areas of low salinity. The species is found to exist throughout the year but restricted to estuarine conditions.

Genus ***Bankia***

**1. *Bankia rochi*** Moll: Pallet elongate, solid and calcified with a long, slender and cylindrical stalk, the blade composed of a series of closely to moderately spaced conical segments, each broadly U-shaped. (Fig.1: a, b, c, d, e & f). Found along the east and west coasts of India, especially in Sunderbans, attacks the mangrove trees even in the living condition.

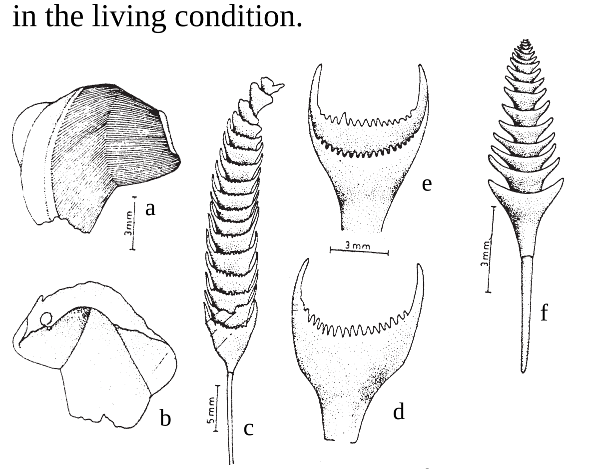



Fig. 1. *Bankia rochi* Moll. (a) Outer view of shell. (b) Inner view of shell. (c) Outer view of pallet. (d, e & f) Inner view of pallet. (Nair and Salim, 1994).

In general, crustacean larvae of several species contribute largely to the abundance of zooplankton observed in the mangrove habitat. The shallow muddy and brackish water environment is thus becomes a paradise of aquatic animals like crustaceans, molluscs and fishes. Some of the crabs like the mangrove or mud crab (*Scylla serrata*), the tree climbing crab *Sesarma* and the fiddler crab *Uca* are the characteristic crustaceans of the environment.

It has been observed that among the seven mangrove centers investigated in Kerala Chettuva displayed the maximum diversity of crustaceans followed next in line by Kumbala and the least in Mangalavanam. All the species of copepods listed whether they are calanoids, harpacticoids, poecilostomatoids or harpacticoids were recorded from this mangrove area. Postlarvae of *Penaeus indicus*, *Metapenaeus dobson*i and *Acetes erythraeus* occurred frequently in the plankton samples collected from here during April-June and the average number varied from 7-10 /$m^3$. It is also significant to note that approximately 3-5 crores of postlarvae of *P.indicus* and *M.dobsoni* are collected for aquaculture purposes every year during November –February from Chettuva.

Juveniles of *Penaeus indicus* dominated (209/$m^3$) the samples collected from Kumbala during the postmonsoon period especially in December and postlarvae of the same species in moderate numbers (10/ $m^{3)}$ during March. Postlarvae of *P.indicus* and *Acetes indicus* also occurred in Koduvally in May and July respectively. The isopod *Cirolana fluviatilis* in Chettuva, the cirripede *Balanus amphitrite* and larval decapods of penaeidae and brachyuridae were observed frequently in abundance at Kujimangalam along with the other crustacean microfauna. The predominant species of the amphipods was *Melita zeylanica* and among the mysids *Mesopodopsis orientalis* and *M. zeylanica* were the common plankters in the mangrove environments of Kerala.

Among the copepods, the harpacticoid *Euterpina acutifrons* occurred throughout the ecosystem. The tanaids were another common mangrove constituent that appeared in large numbers especially during the monsoon season in the mangroves. *Tanais philetaerus* or *Apseudes chilkensis* or both occurred together and especially at Kumbala the total concentration of the tanaids was the highest (126/$m^3$) during June-July.

It can be safely concluded from the present investigations on mangroves of Kerala that there is great potential for the crustacean microfauna of economic importance from certain centres particularly Chettuva, Kumbala and Kunjimangalam and can be harvested yearly if proper conservation measures are taken in time to prevent depletion. As such studies on mangroves are conducted with a view to give guidelines for sustainable, multipurpose-use management of the ecosystem.

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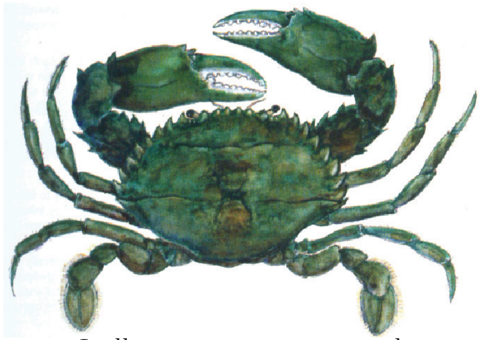
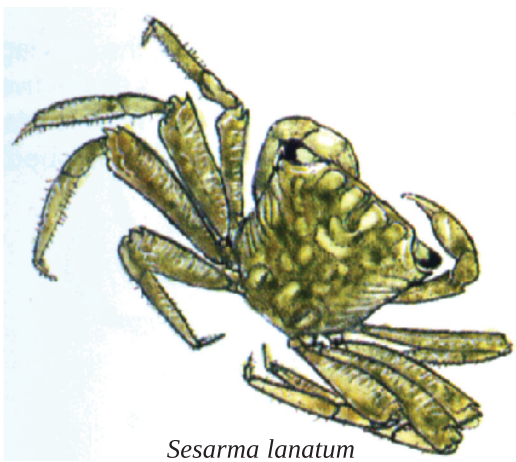
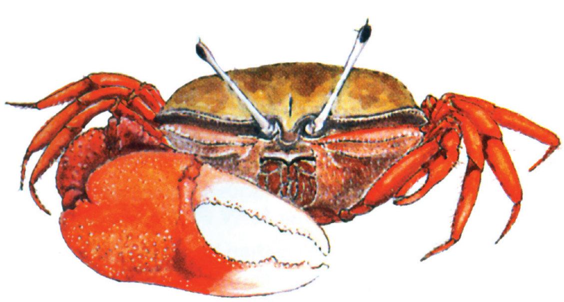


*Scylla serrata* - mangrove crab



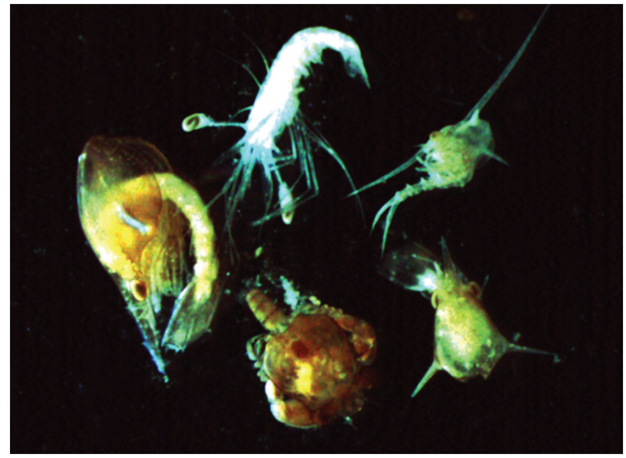
*Sesarma lanatum*

*Thalamita crenata*

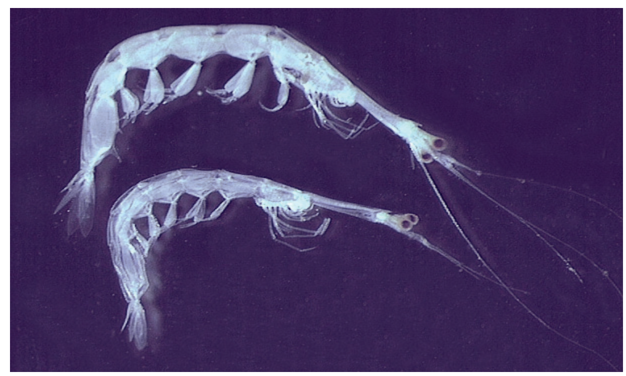


*Uca* sp.

## Common crabs of the mangrove ecosystem

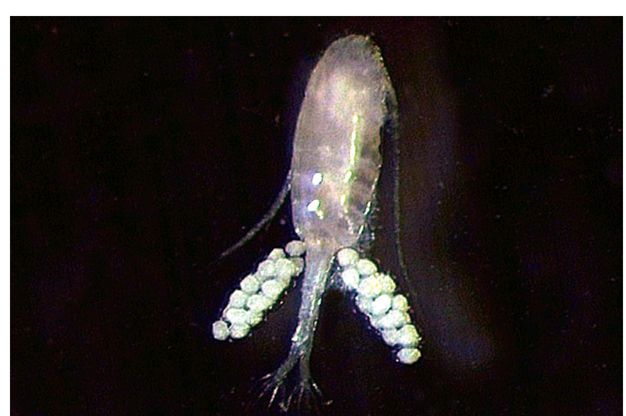


Decapod larvae



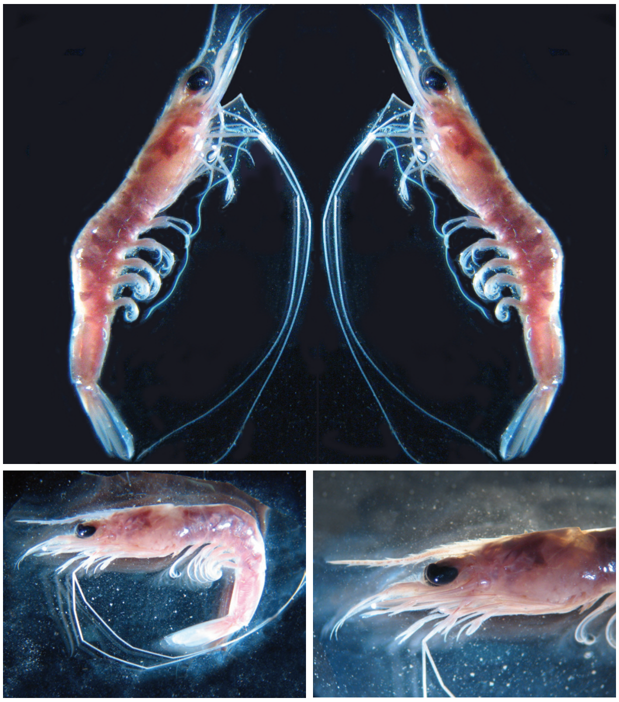
*Lucifer hanseni*

*Pseudodiaptomus annandalei*

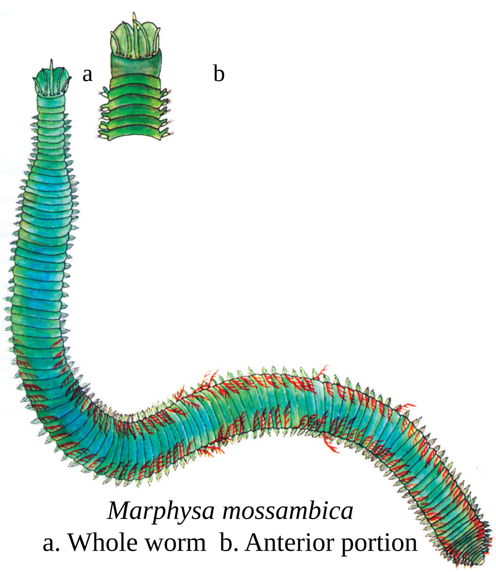


*Pseudodiaptomus serricaudatus*

## Common zooplankton of the mangrove ecosystem



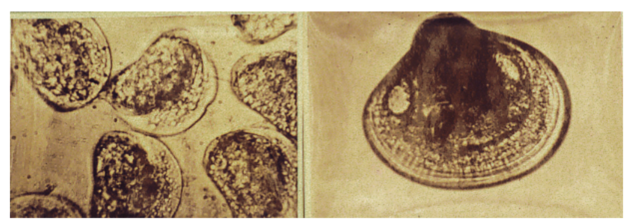
Juveniles of *Penaeus indicus*




*Marphysa mossambica*
a. Whole worm b. Anterior portion

*Meretrix meretrix*

*Cirolana fluviatilis*



Spat stages bivalves

*Perna viridis*

*Paphia malabarica*

# Ichthyofauna of the Mangrove Ecosystem

**Geetha Antony, George J. P., Ansy Mathew, Sunirmal Giri, Gurudas Chakravarty, S. K. Chakraborty, S. Dam Roy**

**Introduction**

The mangroves are breeding, nursery, feeding and hiding grounds for a certain group of finfish, crustacea and shellfish among the aquatic fauna and include those which enter from the sea as well as those which migrate down from the upstream stretches of rivers. An inventory of the ichthyofauna of the mangrove ecosystems has been prepared as part of a NATP project to assess the biodiversity.

**Objectives of studies on fish eggs and larvae**:

1. To know more about larval development:

   Morphogenesis in fish is of biological interest in view of the change from a pelagic egg and almost passive yolk-sac larvae to a freely moving and feeding post-larvae and later on to a shoaling or demersal juvenile. Amongst the vertebrates only fish and amphibians pass through several developmental stages with such great biological and ecological differences.

2. To know more about marine and fresh water ecosystems:

   Fish eggs and larvae are important prey organisms, predators and grazers. Further more they can be used as indicators for the status of pollution and for natural and man-made changes in the ecosystem because larval populations are part of the ecosystem and react to any change in the system and their relationship to the abiotic environmental parameters.

3. To be able to rear fish larvae for aquaculture, re-seeding, ranging and introduction of fish population in natural habitats.

4. To know more about fish population: Fish eggs and larvae are used as indicators of the existence of adult stocks. It is reported that long time series of ichthyoplankton data is more reliable than from fisheries to describe long-term changes in the abundance and distribution of fish stocks.

The present work on the ichthyofauna, provides taxonomic description and biological information of the larvae, juveniles and adult fish from selected mangroves of India.

**Methodology**

The series method of study was applied on the icthyoplankton. Collection from a site may contain larvae of a species in various stages of development or such closely resembling material may be available from different collections. The larvae are sorted out to a series in sequences of size and development. The progressive developmental process leave a trace of the immediate previous stage and the latest stage show close resemblance to juvenile characteristics especially to meristic and partly morphological features of the adult. The built up series enable confirmation of the identity of the material. The easiest method in assessing the fish larval population is to identify the largest stage and work down to the smallest.

**Identification of larvae**

The larval stage includes that stage prior to the acquiring of juvenile characters and the transition stage when juvenile characters are acquired. The juvenile stage is defined as the stage in which all the fin elements are present. In some cases there is the specialized juvenile stage which is found only in a few groups of fishes. The standard larval terminologies used are as follows:

Embryo - Developmental stages to the moment of hatching.

Larva - Developmental stages well differentiated from the juvenile and intervening between the moment of hatching and transformation; commonly divided into Prolarva and Postlarva.

Prolarva - Still bearing yolk.

Post larva - Larva following the absorption of yolk applied only when the structure continue to be strikingly unlike that of juvenile.

Alevin - Larva of species in which post larval stages are not recognized i.e. in which the yolk bearing larva transforms directly into the juvenile.

Juvenile - Young essentially similar to adult.

When larvae from a specific area is studied, basic information on the endemic and migrant adult species occurring in the area is to be known. It is also important to have clear knowledge of the meristic (countable) characters of the adult fishes.

At least four major characters are to be taken into account for identification of fish larvae. They are:

1. Morphometrics: Measurements of body parts over a size range of specimens from larva to early juvenile stage (Fig.1). Changes in body proportions such as in body depth, head size, gut length, shape of viscera; fin positions including size at end of yolk sac stage and size at transformation stages.
2. Meristics: Countable structures such as myotomes or vertebrae, number of fin rays etc. It is possible to count fin rays and vertebrae in transparent post larvae but in less transparent juveniles it is necessary to resort to alizarin staining.
3. Pigment patterns and their changes during early stages (Fig.2). Melanophores are somewhat variable on larvae of the same size; may be expanded or contracted at the time of preservation and can be destroyed by exposure to light or through improper preservation.
4. Specialised larval characters such as spines on opercular bones or head; shape of eyes (sub-circular, stalked etc); elongated dorsal/ventral rays or spines, extended snout etc.

The very shape of the larvae itself broadly distinguishes the major groups from each other. e.g.: clupeids - elongate; scombroids, perches and carangids-laterally compressed. It may be instructive to look at the salient diagnostic features applicable to different groups of fish larvae :

**Body Shape:**

| | |
|---|---|
| Body elongated: | |
| Slender | Clupeidae, Dussumieridae, Engraulidae, Belonidae, Hemirhamphidae, Syngnathidae Synodontidae, Fistularidae. |
| Body rather slender | Sphyraenidae, Sillaginidae, Mullidae, Bregmacerotidae, Gobiidae, Trypauchenidae, Cynoglossidae. |
| Ribbon like body | Ophichthidae |
| Body Short: | |
| Moderate short | Mugilidae, Serranidae, Theraponidae, Carangidae, Lutjanidae, Leiognathidae, Sciaenidae, Thunnidae, Scombridae, Scomberomoridae, Apogonidae. |
| Deeply compressed | Bothidae, Cynoglossidae, Pleuronectidae, Soleidae. |
| Oval body | Monacanthidae, Balistidae, Antennaridae. |
| Depressed body | Platycephalidae, Pagasidae, Dactylopteridae. |

**Head:**

| | |
|---|---|
| Crest on nape | Holocentridae, Carangidae, Leiognathidae, Coryphaenidae, Scorpaenidae, Platycephalidae. |
| Barbel on lower jaw | Exocoetidae |
| Elongated tentacle on operculum | Champsodontidae |
| Bony ridge over eyes | Carangidae, Stromateidae, Holocentridae, Histiophoridae, Scorpaenidae. |
| Protruded snout | Holocentridae, Histiophoridae, Pegasidae, Exocoetidae, Hemirhamphidae. |
| No spines on operculum | Labridae, Gobiidae, Trachypteridae. |
| Spines on operculum | Majority of Perciformes, Scorpaeniformes. |

**Fins:**

| | |
|---|---|
| Pelvic fins abdominal | Isospondyli, Iniomi, Scomberosox.<br>They are soft rayed fishes lacking spines in the dorsal, anal and pelvic fin. |
| Single short dorsal fin | Gonostomatidae, Clupeidae, Engraulidae, Dussumieridae. |
| Single long dorsal fin | Bregmacerotidae, Serranidae, Carangidae, Coryphaenidae, Leiognathidae, Histiophoridae, Stromateidae, Bothidae, Pleuronectidae, Soleidae, Cynoglossidae. |
| Two dorsal fins | Mugilidae, Apogonidae, Mullidae, Gobiidae. |
| Pectorals enlarged | Exocoetidae, Stromateidae, Calliyonomidae, Platycephalidae, Champsodontidae. |
| Ventral fins absent | Angulliformes, Syngnathidae, Tetradontidae. |
| Elongated fin rays on dorsal | Bothidae, Soleidae, Cynoglossidae, Bregmacerotidae. |
| Elongated spines on the dorsal and ventrals | Serranidae, Ballistidae, Acanthuridae. |

**Alimentary canal:**

| | |
|---|---|
| Long and straight | Many Gonostomatidae, Clupeidae, Synodontidae. |
| Bulged or sac like | Cynoglossidae, Soleidae. |
| Short and coiled | Majority of Perciformes. |

**Anal opening:**

| | |
|---|---|
| At middle of body | Apogonidae, Carangidae, Thunnidae, Scombridae, Gobiidae, Scorpaenidae, Pleuronectidae, Bothidae. |
| Behind middle of body | Apodes, Hemirhamphidae, Exocoetidae, Fistularidae, Mugilidae, Sphyraenidae, Coryphaenidae. |
| Far backwards | Stomiatoids, Clupeides, Synodontids. |
| Far forwards | Bregmacerotidae, Atherinidae, Blennidae, Trypauchenidae. |

**Pigmentation :**

| | |
|---|---|
| Dense | Exocoetidae, Hemirhamphidae, Holocentridae, Mugilidae, Coryphaenidae, Histiophoridae. |
| Partial | Atherinidae, Bregmacerotidae, Mullidae, Apogonidae, Stromateidae, Theraponidae, Platycephalidae. |
| Blotches, spots | Engraulidae, Clupeidae, Synodontidae, Carangidae, Apogonidae, Serranidae, Leiognathidae, Thunnidae, Scromberomoridae, Pleuronectidae, Cynoglossidae. |
| **Eye stalks present :** | Asteronesthidae, Bathylagidae, Myctophidae. |

**Myotomes/Vertebrae:**

| | |
|---|---|
| Less than 24 | Calliyonomidae, Balistidae, Monacanthidae, Diodontidae, Tetradontidae, Molidae. |
| 24 | Mugilidae, Sphyraenidae, Carangidae, Mullidae, Istiophoridae, Teraponidae, Leiognathidae, Serranidae, Lutjanidae, Ambassidae, Gobiidae and many others. |
| 30-50 | Clupeidae, Engraulidae, Gonostomidae, Myctophidae, Coryphaenidae, Labridae, Scombridae, Thunnidae, Sillaginidae, Chirocentridae, Scomberomoridae, Bregmacerotidae, Exocoetidae. |
| 51-80 | Elopidae, Albulidae, Megalopidae, Chirocentridae, Beloniformes, Syngnathidae. |
| 100-200 | Anguilliformes, Trichiuridae, Gempylidae. |

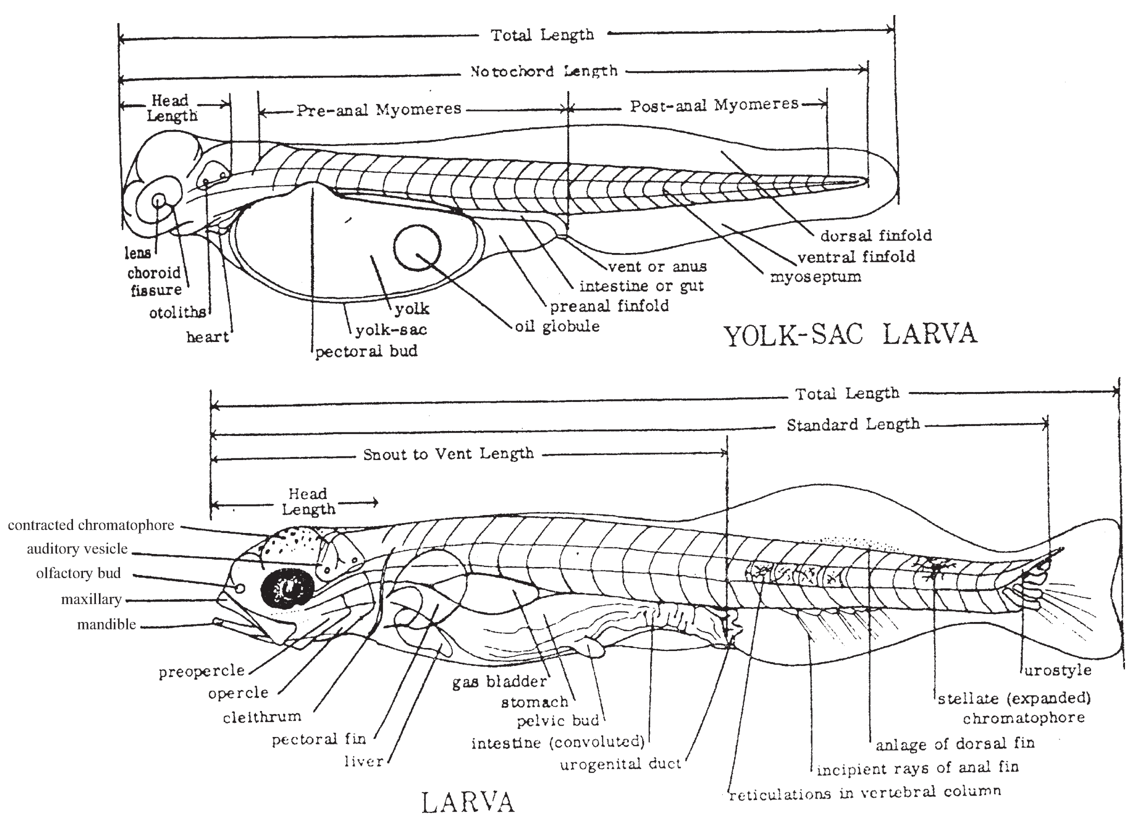



Fig. 1. Diagrammatic representation of morphology and development of egg and larval stages of a typical teleost (Jones *et al.,* 1976).

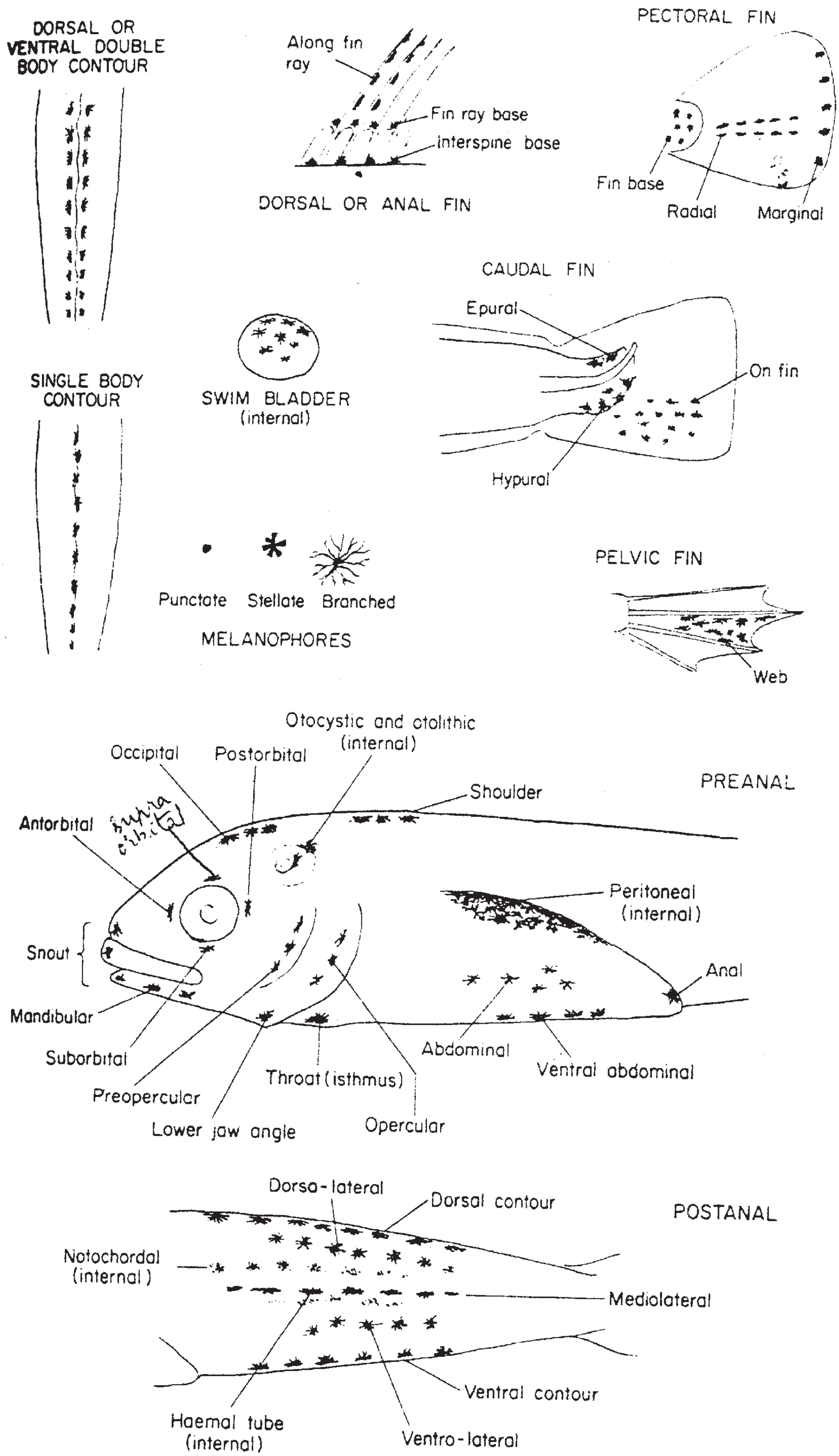
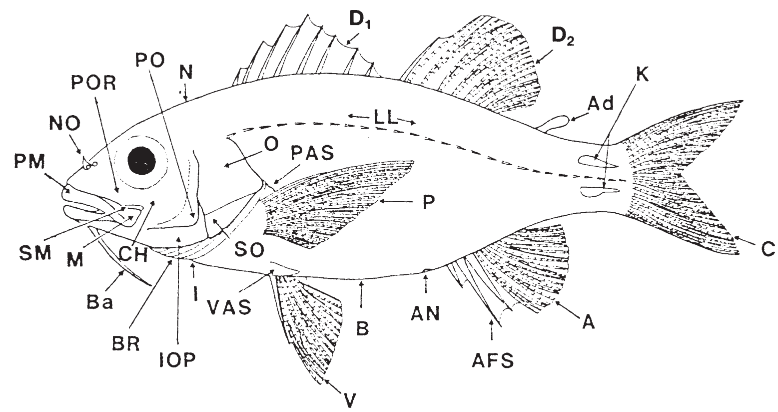


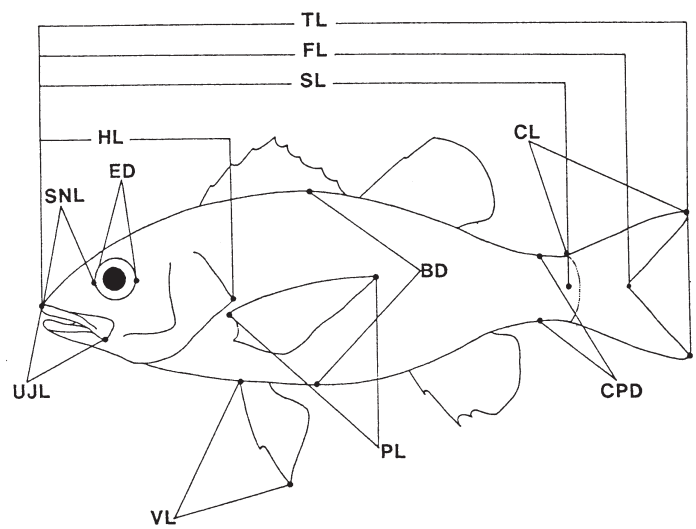

Fig. 2. Illustrating terms used in describing the melanophore pigmentation and fin structure of the postlarva (Russel, 1976)

3.1

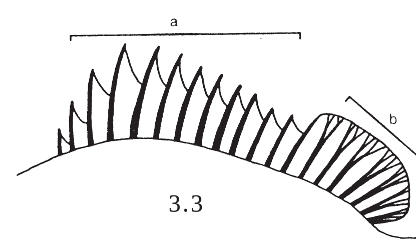



| | | | | | |
|---|---|---|---|---|---|
| A | anal fin | $D_2$ | second dorsal fin (generally with single spine in front of soft-rays) | O | opercle |
| Ad | adipose fin | I | isthmus | P | pectoral fin |
| AFS | anal fin spine | IOP | interopercle | PAS | axillary scale of pectoral fin |
| AN | anus (vent) | K | keels on caudal peduncle | PM | premaxilla |
| B | belly | LL | lateral line | PO | preopercle |
| BA | barbel | M | maxilla (plural: maxillae) | POR | preorbital (lachrymal) |
| BR | branchiostegal rays | N | nape | SM | supramaxilla |
| C | caudal (tail) fin | NO | nostrils (nares) | SO | subopercle |
| CH | cheek | | | V | pelvic (ventral) fin |
| $D_1$ | first dorsal fin (generally spinous) | | | VAS | axillary scale of pelvic fin |

3.2

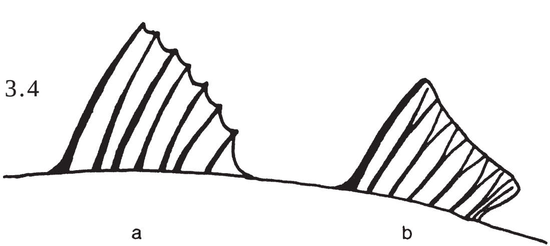



| | | | | | |
|---|---|---|---|---|---|
| BD | body depth | FL | fork length | SNL | snout length |
| CL | caudal fin length | HL | head length | TL | total length |
| CPD | caudal peduncle depth | PL | pectoral fin length | UJL | upper jaw length |
| ED | eye orbit diameter | SL | standard length (snout to base of caudal fin) | VL | pelvic (ventral) fin length |




3.3

3.4




3.5

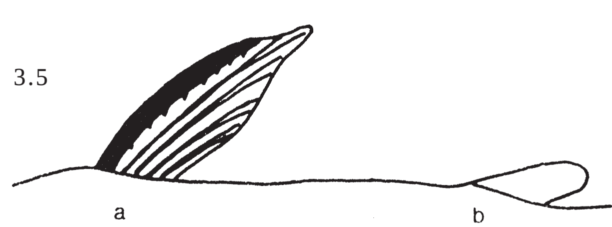



Fig. 3.1. External features of a teleost fish; 3.2. Measurements of a typical fish (Smith, 1986); 3.3 Fused first, spinous (a) and second, soft (b) dorsal fins; 3.4. First, spinous dorsal fin (a) and second, soft dorsal fin (b); 3.5. Rayed dorsal fin (a) and adipose dorsal fin (b).

**Guidelines for identification**

Order **CLUPEIFORMES**

Fin spines absent; a single dorsal fin located above middle of body, pelvic fins abdominal in position, lateral line absent.

Family **CLUPEIDAE**

Elongate larva with long guts. Single short dorsal fin. Median fin development does not begin until 7 mm notochord length. Clupeids develop pigment on the ventral mid line later than 7 mm notochord length (NL). Caudal fin with pigment streaks arranged in an oblique pattern, running down from the dorsal profile to the ventral posterior corner of the caudal peduncle. Early larva show typical crossed muscle fibres.

Genus ***Sardinella***

Larval sardines can be identified from the general clupeoid group by their very rearward positioning of the anus. The gut length is greater than 80% of their notochord length. Myotome number 43-48. General pattern of pigmentation observed in all *Sardinella* species (Fig.4). Pigmentation associated with the caudal area in larva less than 8 mm NL.

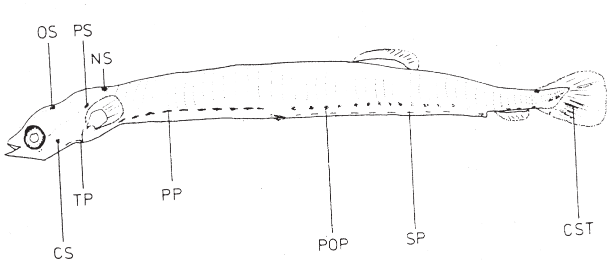



Fig. 4. Diagramatic representation of sardine larva showing pigmentation pattern (Anon, 1974)
OS - Occipital Spot, PS - Pectoral Spot, NS - Neck Spot, CS - Cheek Spot, TP - Throat Pigment, PP - Pre-bladder Pigment, POP - Post-bladder Pigment, SP - Sub-guttal Pigment, CST - Caudal Streaks

***Sardinella longiceps*** Valenciennes, 1847

Fig. 4.1. *Sardinella longiceps* (Munro, 1955)

D 16-17; A 14-15; Lateral scales 46-47; Tr 12-13

Common name Indian oil sardine

Vernacular name Chala, Mathi

Body elongate; belly keeled with scutes along ventral edge; snout not overshot; mouth large, jaws equal; dorsal origin before ventral origin; upper jaw without median notch; last two rays of anal enlarged; ventral rays 9; dark spot at upper edge of opercle.

Larvae with 47-48 myotomes. Larvae below 7 mm total length have 40-43 or more pre-anal myotomes. As the larvae grow older there is a gradual reduction in pre-anal myotomes and an increase in post-anal myotomes. (Fig.4.2 a, b, c). Above 17 mm total length, myotome number is 35 pre-anal and 12 post-anal ones.

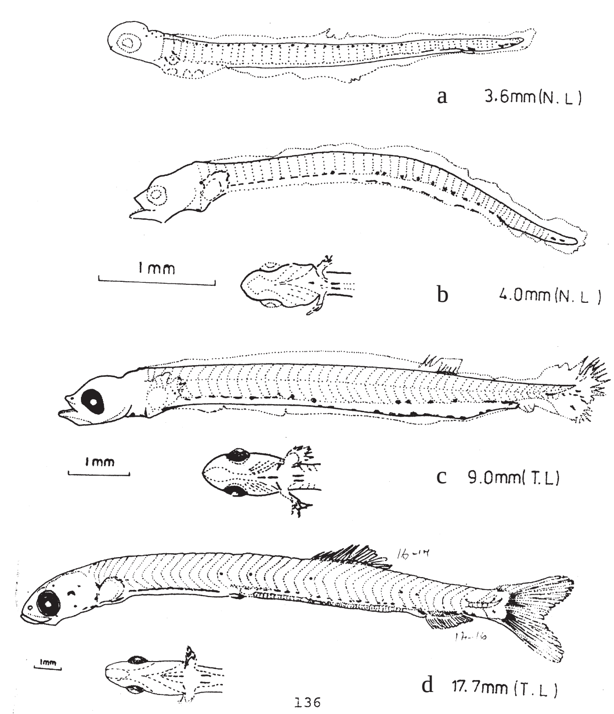



Fig. 4.2 Larvae of *Sardinella longiceps* (Anon, 1974)

Pigmentation of oil sardine larva is of the general pattern observed in all *Sardinella* species (Fig.3). It may vary in the faint or irregular post-bladder pigmentation or in the total absence or weak nature of certain pigments on the head or pectoral spot. Subguttal pigmentation in the form of paired or partly alternating dashes. Cross bars of throat pigments are clearly seen in most of the older larvae.

Distribution, behaviour and utilization: Spawners enter coastal waters forming very large shoals in June-July and juveniles dominate the fishery from November to January off the west coast of India. Feeds on phytoplankton especially diatoms such as *Fragilaria* and other algae. Marketed fresh or canned.

Oil used in industries and for protecting canoes. Fish also used as manure.

Genus ***Dussumieria*** Valenciennes, 1847

Dorsal origin nearer caudal than snout tip.

***Dussumieria acuta*** Valenciennes, 1847.

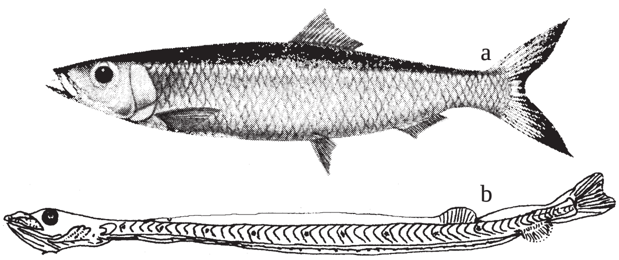



Fig. 5. (a) *Dussumieria acuta* (Day, 1971) (b) larva *Dussumieria* sp. (Vatanachai, 1974)

Common name   Rainbow sardine

D 18-20, A 15-18.

Body elongate, cylindrical, belly rounded without scutes. Base of dorsal slightly longer than base of anal; pelvic fin below middle of dorsal fin base. Pre maxillae rectangular giving distinctive appearance to mouth.

Very slender larvae with a pointed snout; anus situated far backward; myotome number 57, anal opening below $45^{th}$-$48^{th}$ myotome (Fig.5.b).

Distribution : Pelagic inshore species, No special fishery.

Genus ***Hilsa*** Regan

Upper jaw with a distinct median notch at centre. Scales moderate-sized, evenly arranged, 37 to 47 in lateral series; lower edge of operculum at $20^0$ to horizontal, marine or anadromous.

***Hilsa (Tenualosa) toli*** (Valenciennes)

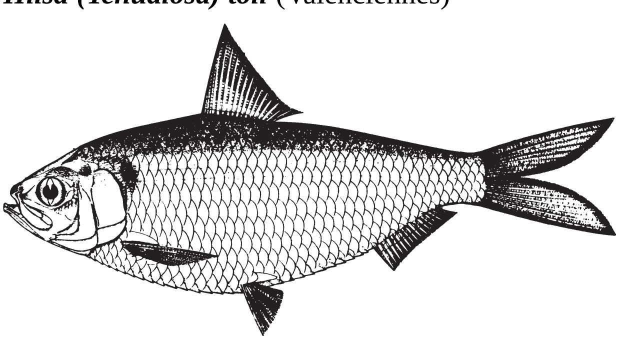


Fig. 6. *Hilsa (Tenualosa) toli* (Talwar & Jhingran, 1991)

Common name   Toli shad

D iv-v 14-15; A iii 15-17; P i 13; V i 8

Body fusiform, moderately deep and strongly compressed; belly with 28 to 30 scutes. Head length 3.6 to 4 times in standard length; a distinct notch in upper jaw. Gillrakers fine, 60 to 100 on lower arm of first arch. Pseudobranch not attenuated, without ventral groove. Caudal fin long, 2.9 to 3.2 times in standard length. Colour in life, silvery shot with yellow and purple; a diffuse dark blotch behind gill-opening.

Distribution : Marine, pelagic and schooling in coastal waters, euryhaline often ascending rivers to breed.

Genus ***Anodontostoma***

Oval deep laterally compressed body, last dorsal fin ray normal; pre-dorsal scale forming a single median row, scutes along ventral border of abdomen.

***Anodontostoma chacunda*** (Ham. Buch. 1822)

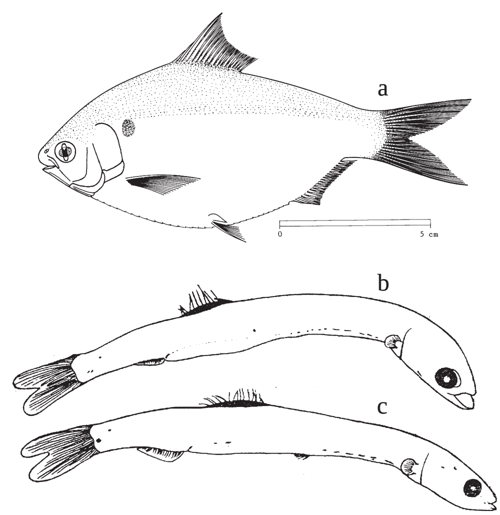



Fig. 7. (a) *Anodontostoma chacunda* (Fischer & Whitehead, 1974); Post-larvae (b) 12.8 mm stage (c) 15.57 mm stage (Bensam, 1967)

Common name   Short nose gizzard shad

Vernacular name   Thodi

D 17-18. A 19-20.

Snout shorter than eye. Mouth inferior, maxilla straight, thin and tapering. Prominent black spot on shoulder.

Myotome number 41; pre-anal 31 and post-anal 10 in the earliest larva which in the 15.57 mm specimen is 30 pre-anal and 11 post-anal. Origin of anal fin far behind the level of the hinder end of the dorsal corresponding to its future disposition. Fins more prominent at 8.7 mm stage, caudal fin become forked in the 12.8 mm stage. Mouth terminal, lower jaw longer than the upper. Pigmentation of the early postlarva (Fig.7.b) consists of a series of chromatophoral streaks along the ventral aspect of the alimentary canal in its anterior half, a few pigment spots in the dorsal aspect of the mid-gut, the body above this region and the hind gut. A few pigment spots occur on the ventral aspect of the caudal region. A few black spots in the median region seen behind the operculum ventrally. Pigmentation at the tip of the lower jaw and along the lateral aspect of the body. 16 dorsal, 16 anal and 24 caudal rays in the 15.57 mm stage (Fig.7.c).

Distribution, utilization: Pelagic inshore species, sometimes in fair number, no special fishery. Marketed fresh.

Family **ENGRAULIDAE**

Sub-cylindrical body, scutes present along belly, snout strongly projecting, lower jaw underslung.

The elongate rod shaped engraulid larva have slightly greater body depth and are less laterally compressed than clupeidae. Median fin development begins at less than 6 mm notochord length. The typical crossed arrangement of muscle bands observed from the very early stage onwards. Melanophores restricted to ventral surface. Fewer melanophores in the foregut series at any given size than clupeidae.

The following changes of body form are characteristic of engraulid larvae: slender body deepens, head becomes round and mouth inferior, dorsal and anal fins shift anteriorly with rapid changes shortly after 15 mm standard length.

Genus ***Stolephorus*** Lacepede, 1803

Scutes needle like, only present between pectoral and pelvic fin bases, anal fin short, less than 25 fin rays.

Larval myotome count 39-42.

***Stolephorus punctifer*** (Fowler, 1938)

Syn. *S.buccaneeri* Strasburg; *S.zollengeri* Bleeker

Common name Buccaneer anchovy

Vernacular name Kozhuva

D ii, 10-13; A ii, 12-15.

Belly rounded with 4-5 needle like scutes between pectoral and pelvic fin bases. Tip of maxilla bluntly rounded reaching only to front margin of preopercle. Compared to other species, dark in colour. The dusky brown lateral band is represented by a fairly silvery band.

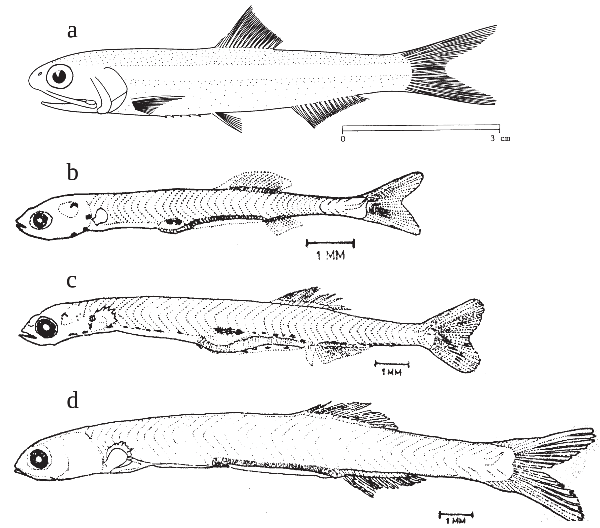



Fig. 8. (a) *Stolephorus punctifer* (Fischer & Whitehead, 1974) larvae (b) 7.5 mm (c) 10.5 mm (d) 15.0 mm (Sreekumari, 1971)

In 7.5 mm larva, anal opening below $27^{th}$ myotome, about four-fifth of the distance to the caudal base. An airbladder noticed as a conspicuous organ. The posterior half of the alimentary canal shows a striated appearance. The peritoneal lining of the abdomen shows a few pigment spots. Pigment lines at the caudal fin region.

In 10.5 mm larva, almost all pigmentation characteristics are present. Pigmentation present throughout the ventral margin; distinct chromatophores at the pectoral base, above the auditory vesicle and near the anal opening. Air bladder portion has three stellate chromatophores followed by pigment lines upto the caudal base. Caudal fin with the characteristic caudal pigment streaks arranged in an oblique pattern running down from the dorsal profile to the ventral posterior corner of the caudal peduncle. Median fins have all the rays developed; pectoral has developed full complement of 13 rays. Pelvic fin rudiment as a thickening at the $13^{th}$ myomere. There are 25 pre-anal and 17 post-anal myotomes (including urostyle).

Ventral fin develops 7 rays in 15 mm larvae. Development of caudal rays complete. Larvae retains its cephalic pigmentation. Slight forward shifting of the anal opening; 27 pre-anal and 14-15 post-anal myotomes.

Distribution, utilization: Pelagic in coastal waters. Marketed fresh or dried salted.

Genus ***Thryssa*** Cuvier, 1829.

Large, more compressed, fishes with a dark humeral area behind gill opening. Anal fin longer with more than 25 fin rays.

***Thryssa dussumieri*** (Valenciennes, 1848)

Syn. *Thrissocles dussumieri* Fowler, 1941

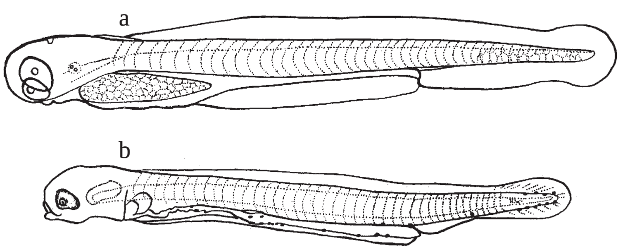



Fig. 9. *Thryssa dussumieri* larvae
(a) 3.9 mm TL (b) 4.6 mm TL (Bensam, 1987)

Common name Mustached anchovy

Vernacular Managu

Myomeres 42. Larva of 3.9 mm has 28 pre-anal and 14 post-anal myomeres. 4.6 mm larva has 29 pre-anal and 13 post-anal myomeres. Pigmentation in the foregut, midgut and hindgut.

***Thryssa mystax*** (Schneider, 1841)

Syn. *Thrissocles mystax* Fowler, 1941.

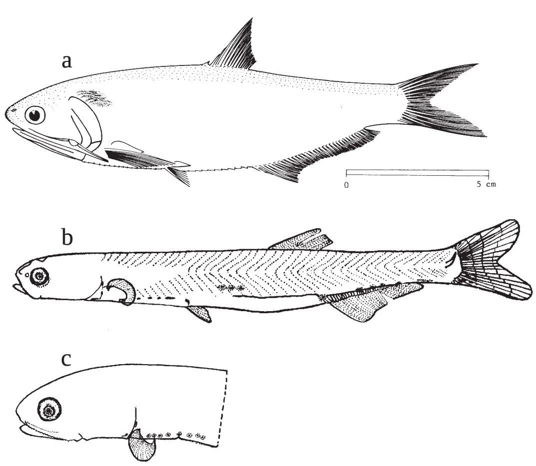



Fig. 10 (a) *T.mystax* (Fischer & Whitehead, 1974) (b) Postlarva 18.8 mm (c) Cephalic region of a postlarva 23 mm (Bensan, 1987)

Common name Mustached anchovy

Vernacular name Manangu

D 15-16, A 36-38.

In adult, belly keeled with 16 to 19 scutes in front of pelvic fin base and 9 to 11 scutes behind. Maxilla long, its tip reaching to base of pectoral fin.

In 18.8 mm larva, myomeres 45; 27 pre-anal and 18 post-anal; 15 dorsal, 6 pelvic, 30 anal and 24 caudal rays. In 23 mm postlarva, snout more prominent, maxillary extends behind eye region; dorsal fin origin is well in front of the middle of the body. Myomeres changed in position, 24 pre-anal and 21 post-anal.

Distribution, utilization: In coastal waters, also in estuaries. Forms significant catches in Kerala. Marketed fresh and dried salted.

Order **GONORHYNCHIFORMES**

Mouth small, toothless, suprabranchial organs (bilateral pouches behind fourth gill arch) present. Eyes covered with skin. Pectoral fin base horizontal; pelvic fins abdominal; well developed scaly axillary process at base of pectoral and pelvic fins; no fin spines. Branchiostegal rays 4.

Family **CHANIDAE**

Body torpedo-shaped, compressed with regular, grooved, cycloid scales. Head naked. Mouth small, maxilla not reaching past centre of eye; jaws toothless. Dorsal fin inserted opposite to pelvic fins. Caudal fin deeply forked. Dorsal and anal fins with basal scaly sheath; large axillary scales above pectoral and pelvic fins.

Genus ***Chanos*** Lacepede

Body compressed; abdomen rounded and smooth. Mouth terminal. Scales small; lateral line present.

***Chanos chanos*** (Forssskal)

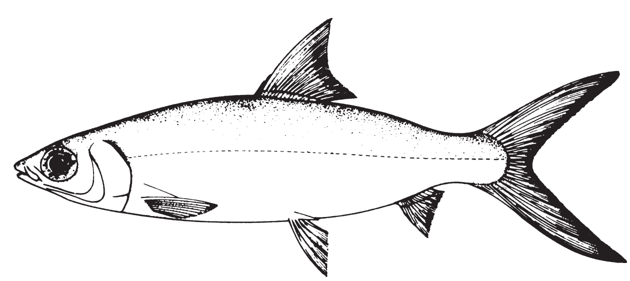


Fig. 11. *Chanos chanos* (Talwar & Jhingran, 1991)

Common name Milk fish

D 13-17; A 9-11; P 15-17; V 11-12

Lower jaw with a small tubercle at tip, fitting into a notch of upper jaw. Dorsal fin inserted at midpoint of body; anal fin short, placed far behind dorsal fin base. Scales small, cycloid; head naked; lateral line with 75 to 90 scales. Colour in life, brilliant silvery, darker dorsally. Caudal and anal fin margins dusky.

A large yolk sac in 3.2 to 5.3 mm larvae. Eyes not prominent, no fin buds. Pre-anal myomeres vary between 33 to 34 and post-anal 8 to 10; anus situated far back. A number of black branching pigment cells are present especially in the dorsal and anal fin folds.

Late larval stage with a total body length of 10-16mm possesses 33 pre-anal myomers. Fine black pigment spots are spread all over the surface of the body with more density in the dorsal region.

Distribution : Inhabits coastal waters entering estuaries, river and lakes. Although an inhabitant of the sea in its adult stages, its fry, fingerlings and even early juveniles can be obtained mostly from the brackish water regions.

Order **MYCTOPHIFORMES**

Fin spines absent; adipose fin present.

Family **SYNODONTIDAE** (Lizard fishes)

Maxilla narrow, less than 20 anal rays. Paired ventro-lateral pigment patches from the very early stage larvae. Slender elongated shape of the larvae retained throughout the developmental stages. No forward movement of any of the fins as in clupeids. Air bladder absent.

Genus ***Saurida*** Valenciennes, 1849

Mouth large with numerous sharp teeth, head lizard like. Myotome number varies from 46 in the newly hatched larvae (4mm), 31 pre-anal and 15 post-anal, to 49 in larvae above 7 mm, 34 pre-anal and 15 post-anal.

***Saurida tumbil*** (Bloch, 1795)

Syn. *Saurida argyrophanes* Richardson, 1846

Common name Greater lizard fish

Vernacular name Arana meen

D 11-13, A 10-11.

Eye less than inter-orbital. Brownish, lighter below, mottled with traces of cross-bars.

Six pairs of peritoneal pigment spots on the ventro-lateral side from the very early stages of development which is species specific (Figs. 12.b-d). The anterior most pair on the posterior border of the gill cleft, below the end of the opercular flap and the last pair in front of the anus. Larvae above 9.9 mm length develop a small dash of pigment behind the posterior 6th pair of pigment spots slightly above the level of anal opening. A branching chromatophore present on the ventral side in between the anal opening and the caudal at the level of the 40th myomere.

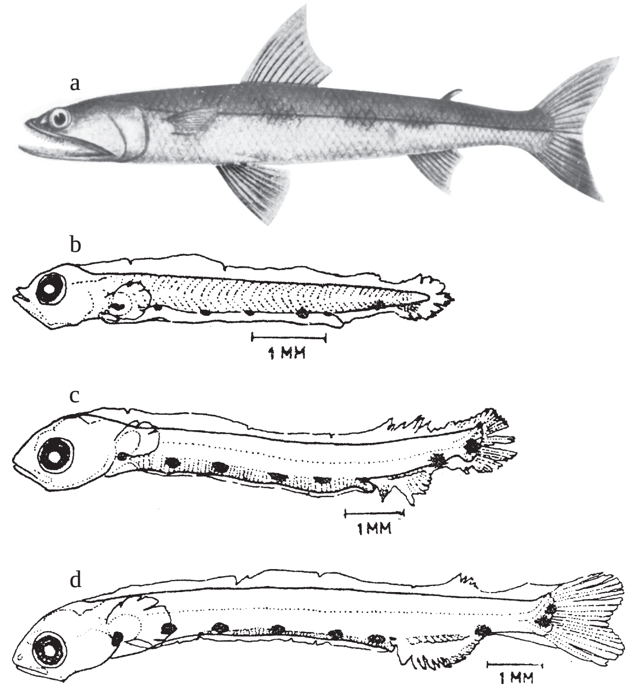



Fig. 12 (a) *Saurida tumbil* (Munro, 1955);
Larvae (b) 5.4 mm (c) 7.4 mm (d) 9.9 mm (Dileep, 1977)

Pigmentation of mid-ventral line between anal fin and caudal peduncle increases and in the juvenile (25-31 mm) the entire anal fin base is pigmented. Dorsal fin formation with 11-13 rays complete by 18 mm stage. Second dorsal fin, an adipose fin devoid of fin rays form above the anal fin as a rounded lobe at 9.3 mm and is fully developed in 15.5 mm larvae.

Distribution, behaviour, utilization: Commonly found on muddy bottoms between 20-60m depth, enter shallow waters. Mainly piscivorous, but also feeds on crustaceans. Marketed fresh.

Order **ANGUILLIFORMES**

Body very elongate; fin-spines absent; pelvic fins absent; usually scaleless.

Family **OPHICHTHIDAE**

Body long, cylindrical anteriorly. Snout pointed, mouth terminal or inferior; teeth on jaws variable with genera, gill openings small. Branchial region and throat swollen supported by a basket of free branchiostegal rays, a unique feature of this family. No spines in fins. Pectoral fins present or absent; pelvic fins always absent.

Subfamily **OPHICHTHINAE**

Dorsal and anal fins discontinuous. Tip of tail finless and pointed.

Genus ***Ophichthus*** Ahl, 1789

Snout moderate or short, jaws stout and short, capable of closing completely.

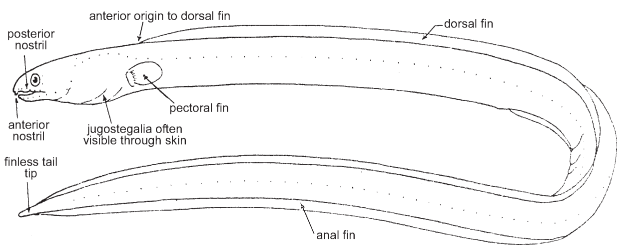



Fig. 13. *Ophichthus* sp. (Fischer & Bianchi, 1984)

Order **CYPRINODONTIFORMES**

Family **HEMIRHAMPHIDAE** (Half beaks)

Body elongate, with a prolonged lower jaw and a short triangular upper jaw. No spines in fins; dorsal and anal fins posterior in position; pelvic fins abdominal, with six rays; pectoral fins usually short; caudal fin rounded, truncate or forked.

Genus ***Zenarchopterus*** Gill

Dorsal fin origin slightly before anal fin; anal fin base shorter than dorsal fin base, 8 to 14 rays. One of the anal soft rays is expanded in width as a secondary sexual character of the male.

***Zenarchopterus striga*** (Blyth)

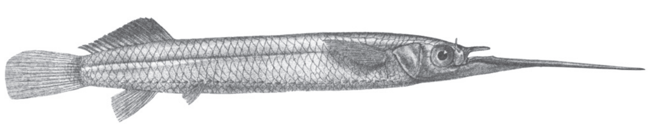


Fig. 14. *Zenarchopterus striga* (Day, 1971)

Common name Hooghly halfbeak

D i 10-11; A ii 7; P i 9; V i 5

Body very elongate and slender, laterally compressed. Upper jaw as long as broad at its base, its length 7.6 to 9.25 times in free lower jaw. Dorsal fin rays normal; sixth and seventh anal rays enlarged and thickened. Predorsal scales 29. Body yellowish; a distinct black lateral stripe with a silvery hue; beak blackish.

Distribution : Inhabits fresh water and estuaries. This halfbeak is of no interest to fisheries.

Family **CYPRINIDAE**

Barbels one or two pairs or absent; no suborbital or preorbital spine; body usually laterally compressed; pharyngeal teeth in one to three rows.

Subfamily **CYPRININAE**

Lower jaw without any symphyseal process; dorsal fin inserted before or opposite to origin of pelvic fins; generally with a spine; lateral line running along median line of caudal peduncle.

Genus ***Puntius*** Hamilton - Buchanan

Lips distinct, no horny covering on inner side of lips; scales with few and strongly radiating striae.

***Puntius sarana subnasutus*** (Valenciennes)

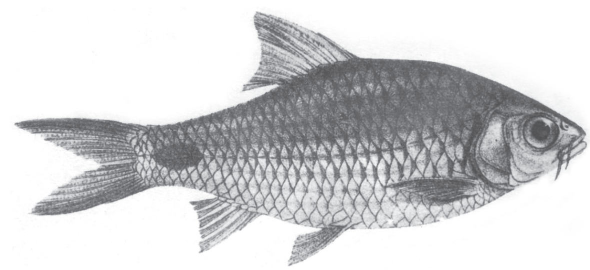


Fig. 15. *Puntius sarana subnasutus* (Day, 1971)

Common name Peninsular olive barb

Vernacular name Kurichi

Diii 8; Aii 5; Pi 16; V i 7

Body oblong and fairly deep, its depth 2.7 to 2.9 times in standard length. Head fairly small, its length 4.4 to 3.8 times in standard length. Eyes moderate, its diameter about 3.5 times in head length. Mouth moderate; barbels two pairs, maxillary pair much longer than orbit, rostral pair slightly shorter. Dorsal fin inserted equidistant between tip of snout and base of caudal fin; its last unbranched ray osseous, fairly strong (weak in young) and posteriorly serrated. Scales moderate; lateral line complete, with 28 to 31 scales; predorsal scales 10.

Colour : A dark band behind operculum and a black blotch on lateral line on about 24th scale. Fins orange; caudal fin with a black superior and inferior edge.

Distribution : River systems of peninsular India, very common in the Kerala backwaters.

Fishery information : This barb attains a length of 25 cm. It is of considerable economic importance.

Subfamily **RASBORINAE**

Lower jaw generally with a symphyseal process, fitting in a notch of emargination of upper jaw; dorsal fin inserted behind base of pelvic fins, devoid of a spine; lateral line if present, abruptly bend downwards and if complete, running along lower half of caudal peduncle.

Genus ***Danio*** Hamilton-Buchanan

Lower lip present, mouth small to moderate, maxilla not extending beyond vertical through anterior margin of eye, lower jaw with a symphyseal process. Anal fin with 13 to 20 rays; dorsal fin inserted anterior to origin of anal fin. Lateral line complete.

***Danio aequipinnatus*** (McClelland)

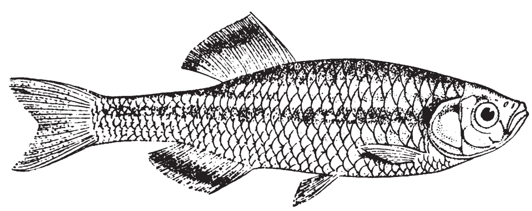


Fig. 16. *Danio aequipinnatus* (Day, 1971)

Common name Giant danio

D ii-iii 9-12; A ii-iii 14-16; Pi 11-12; Vi 6

Body elongate and compressed; its depth 2.9 to 3.5 times in standard length. Head length 3.5 to 4.3 times in standard length; snout length 3.3 to 5, eye diamter 3 to 4, both in head length.

A pre-orbital spine, backwardly directed from lachrymal bone.

Mouth small, directed upwards; barbels two short pairs, rostral pair about half eye-diameter, the maxillary barbels minute.

Dorsal fin inserted well in advance of origin of anal fin, extending to over anterior anal fin rays. Caudal fin forked. Lateral line complete with 35 to 37 scales; predorsal scales 14 or 15.

Colour : A well marked lateral band of dark blue along sides which runs along the entire length from caudal fin to head, breaks up into three bands in adults separated by golden lines before reaching gill opening; a well defined black blotch near upper angle of gill opening generally present.

Distribution : A widely distributed and beautiful species of the fresh waters of our area; an ideal aquarium fish.

Family **HORAICHTHYIDAE**

Small, translucent, elongate and more or less strongly compressed fishes. Mouth comparatively large, premaxillaries not protractile. Anal fin long with 28-32 rays. In males, the six anterior rays of the anal fin are separated from the rest of the fin and modified into a large gonopodium. Dorsal fin is short and situated behind the anal. In females the right pelvic fin is usually absent. Caudal fin rounded. Genital opening of the female asymmetrically situated and the region surrounding it strengthened by the development of genital pads.

Genus ***Horaichthys*,** Kulkarni, 1940

Anal rays form gonopodium, genital opening of female shifted to one side and callous pads developed around it. Right pelvic fin absent in females.

***Horaichthys setnai***, Kulkarni, 1940

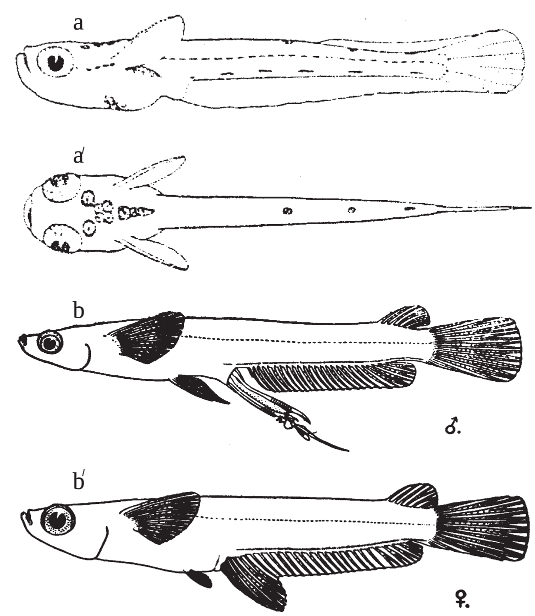



Fig. 17. *Horaichthys setnai* Kulkarni. (a, a′) Newly hatched larva in lateral and dorsal views x 20 (b, b′) adults (Kulkarni, 1940)

Common name Thready top-minnow

D 6-7; A 28-32; V 5

Head slightly depressed; mouth directed upwards; teeth sharp and conical on both jaws. In female, anal fin rays simple but the second to sixth rays more elongated, pectoral fins large and well developed thick muscular bases. Colour in life nearly transparent; head with a prominent dark occipital spot behind eyes and number of minute spots scattered all over as well as on upper margin of jaws.

Newly hatched larvae measures 3.5-4.0 mm. Body laterally compressed and tapers to the caudal extremity. Eyes and mouth well developed. Minute teeth in lower jaw. Pectoral fins fully developed, have a broad base and are placed high up at the sides of the body. Vertical fins appear as continuous fin fold starting dorsally at about 2/3 of the body from the anterior end and pass round the caudal region. No other fins are present. Larvae almost transparent except for the prominent black eye and a few dark spots on the head. The number of these large chromatophores are not constant; generally they are 2-4 in number. The second pair of the chromatophores on the head fuses at times to form a large chromatophore in the centre of the head. As seen in Fig.17 a' there are two or three smaller chromatophores behind the larger ones followed by three or four still smaller, slightly oblong black spots on the mid dorsal side of the body. These spots are absent in some larvae. A row of dash-like black spots present in the middle of the body on the lateral line; so closely set that they form an almost continuous line. There is another row of five or six dots similar to those on the dorsal side and situated just above the base of the ventral vertical fold on both sides. A number of small black dots visible in the axilla of the ventral fins. On the abdomen there are four or five irregular chromatophores. A few tiny spots present on the caudal rays.

In 10 mm larvae pelvic fins visible; these fins are paired in some and single in others. Individuals with paired fins are in majority of cases males, while those with only one fin are females. Anal fin is similar in both sexes with 28-32 fin rays. Dorsal and anal fin have developed rays and are quite distinct from caudal. Some pigment spots have become smaller but this number has increased considerably on different parts of the body. The morphological development is complete in 12 mm larva.

Fishery information: Hardly 2 cm in length, it is the smallest known fish in India. An estuarine species capable of living temporarily in fresh water. Being always on the surface water, it destroys the early instars of mosquitoes and other insects.

Order **SILURIFORMES**

Barbels around the mouth

Family **BAGRIDAE**

Dorsal fin with a pungent spine, caudal not pointed, not united with dorsal. Anal short. Nostrils not close together; posterior one with barbel. Head and body smooth; size up to 1 m.

Genus ***Mystus*** Scopoli

Eyes not covered with skin; barbels usually longer than head. Interneural shield absent.

***Mystus gulio*** (Hamilton-Buchanan)

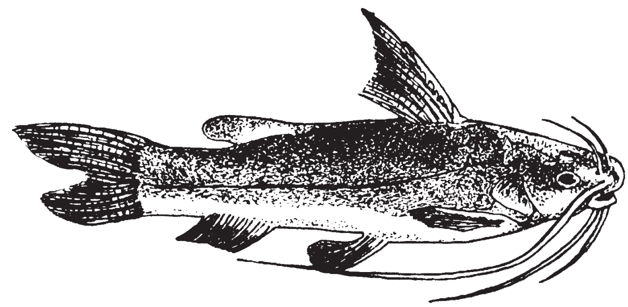


Fig. 18. *Mystus gulio* (Misra, 1976)

Common name Long-whiskered catfish

D I 7; A iii-iv 9-11; P I 8-9; V i-5

Differs from all other *Mystus* by its adipose whose base is shorter than base of anal. No dark blotch on base of caudal fin; occipital crest rugose; branchiostegal rays 9.

Distribution : In estuaries and coastal waters.

Family **ARIIDAE**

Paired maxillary and mandibularly barbels either both present or one type absent. Dorsal fin short with a more or less serrated spine followed by 7 soft rays; Adipose fin present, relatively short fins; caudal fins forked.

Genus ***Arius*** Valenciennes

Both mandibularly and maxillary barbels present. Teeth on palatine. Teeth on hind margin of dorsal spine directed downwards.

***Arius arius*** (Hamilton-Buchanan)

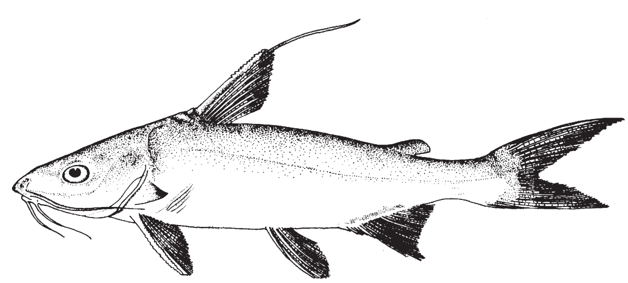


Fig. 19. *Arius arius* (Jayaram, 1982)

Common name Threadfin sea catfish

DI 7; AV-VI 14-16; PI 10; Vi 5

Body elongate and robust; head depressed; median fontanelle groove on top of head shallow, not reaching to base of supra occipital process.

Barbels three pairs; maxillary barbels reaching to anterior third of pectoral fin. Mouth subterminal and narrow; jaw teeth villiform; teeth on palate globular, in a single large ovate patch on each side with a horn like conical projection anteriorly.

Tip of dorsal spine prolonged into a filament. Adipose fin with a well defined black spot.

Distribution : Inhabits seas, estuaries, tidal waters and brackish water lakes.

Order **SCORPAENIFORMES**

Cheeks with a bony extension of suborbital bone to preopercle. Well developed spines on head and prominent spines in dorsal fin; pectoral fins usually rounded; caudal fin rarely forked.

Family **PLATYCEPHALIDAE**

Elongate fishes with head moderately to strongly depressed. Larvae with crest on nape. Juveniles and adults with bony ridges of head usually bearing spines or serrations. Pectorals enlarged. Two dorsal fins well separated; pelvic fins thoracic in position set far apart towards sides of body. Vertebrae 27; pre-anal 12 + 15 post-anal.

Genus ***Platycephalus*** Bloch, 1795

Pored scales in lateral series 65 or more; teeth on vomer in one tranverse patch. Soft dorsal rays 13.

***Platycephalus indicus*** (Linnaeus, 1758)

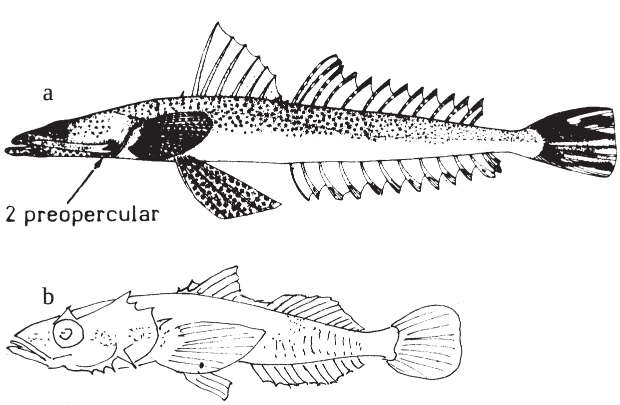



Fig. 20. (a) *Platycephalus indicus* (Talwar & Jhingran, 1991)
(b) *Platycephalus* sp. larva 9.8 mm (Vatanachai, 1974)

Common name Bartail flathead

DI/VIII/I + 13; A13

Head bearing smooth bony ridges, preocular and preopercular spines.

***Cociella crocodilus*** (Fischer and Bianchi)

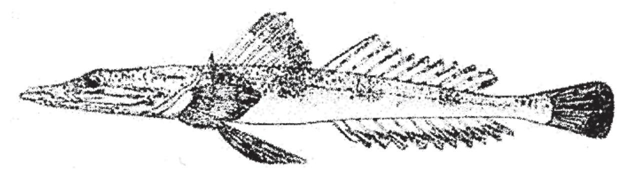


Fig. 21. *Cociella crocodilus* (Fischer & Bianchi, 1983)

D IX, 11; A 11.

51 to 55 pored scales in lateral scale series; only the anterior 2-16 pored scales of the lateral series bearing spines.

Order **PERCIFORMES**

Either 2 dorsal fins or one dorsal fin with the anterior elements being sharp spines; pelvic fins with 1 spine and 5 soft rays placed well forward on ventral surface of body.

Family **CENTROPOMIDAE**

Body elongate or oblong, moderately compressed with a deep caudal peduncle. Mouth large with lower jaw longer than upper. Opercle with a single stout spine; preopercle with a serrated posterior border. Dorsal fin deeply notched almost dividing spinous from soft rayed part. Pelvic fins below pectoral fin. Caudal fin rounded.

Genus ***Lates*** Cuvier

Head rather pointed, with concave dorsal profile at nape and becoming convex in front of dorsal fin. Upper jaw reaching to behind eyes. Horizontal limb of preopercle with 3 or 4 large, flattened and triangular spines.

***Lates calcarifer* (Bloch,1790)**

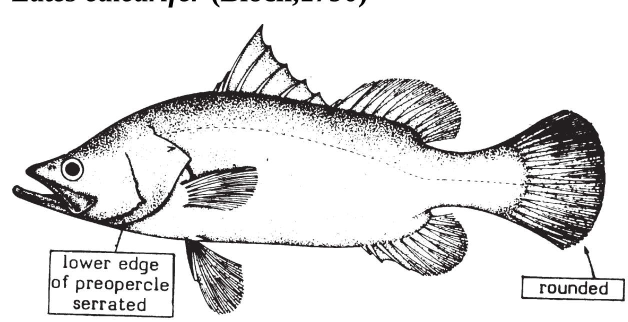



Fig. 22. *Lates calcarifer* (Talwar & Jhingran, 1991)

Common name Barramundi

D VII-IX + I 10-11; A III 7-8; P 17; V I 5

Mouth large, slightly oblique, teeth villiform on jaws; some teeth on tongue. Colour in juveniles olive brown above with silvery flanks and belly or green like above and silvery below.

Larvae measure about 1.5 mm in length immediately after hatching. In the larvae with body length of 4mm, two large branching chromatophore are present behind the eye and three large chromatophores in the middle region of the lateral sides. 8 pre-anal myomeres and 12 post-anal myomeres are countable; chromatophore in dense patch on the dorsal side of the gut and along base of the dorsal fin.

Early juveniles are darkly pigmented; Specimens measuring 20mm in length and above possess a brown band or stripe running between the snout and the dorsal fin with 3 to 5 dark grey vertical bands of chromatophores. The larval preopercular spines are reduced as a serration and only one strong spine exists. The opercular spine is yet to develop in early juveniles of less than 30mm in length.

Distribution: A coastal and estuarine species; enter estuaries in pursuit of food and shelter but return to marine environment for spawning.

Family **CARANGIDAE**

Myotome count quite stable (24) except in some genera. Armature of the head is another important character distinguishing the genera from each other. The long and strong spine on preopercle is at the corner between its horizontal and vertical edges. Sagittal crest- its presence or absence, its shape, position and its denticulations distinguish some genera and species. Anal spine separate from the rest of the fin, more dorsal fin rays than anal rays. Body pigmented; pigmentation increases in post larvae and juveniles.

Genus ***Scomberoides*** Lacepede, 1801

Laterally compressed elongated body with 6-7 short and stout dorsal spines. Myotome number 26.

***Scomberoides lysan*** (Forsskal, 1775)

Syn. *Chorinemus sanctipetri*(Cuv & Val)

Common name Double spotted queen fish

D VI-VII + I 19-21, A II + I 17-19

Body strongly compressed. Upper jaw extends to posterior margin of eye in adults. Gill rakers 21-27 on first arch. Posterior soft dorsal and anal fin rays consisting of semidetached finlets. Adults with a double series of 6 to 8 dusky roundish blotches above and below lateral line; distal half of dorsal fin lobe abruptly and heavily pigmented.

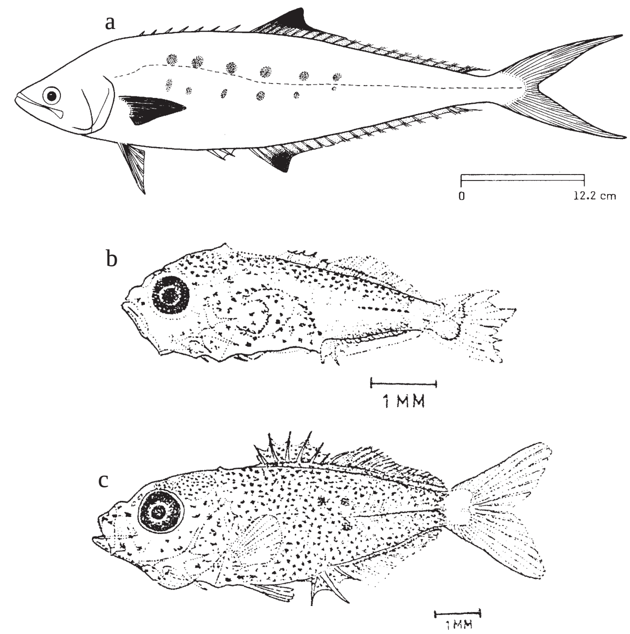



Fig. 23. (a) *Scomberoides lysan* (Fischer & Bianchi, 1983) larvae (b) 6 mm (c) 10 mm (Premalatha, 1971)

Body of larvae short, mouth oblique in position with a few pigments at its tip, upper margin of lower jaw serrated; 4 opercular spines, 2-3 in the horizontal portion, 3rd one at the corner between the horizontal edge and the ascending part of the pre-opercular; below the third spine is the fourth one which is longer than the rest. A small point like crest behind occipital. Out of 26 myotomes, 10 pre-anal and 16 post-anal. The chromatophores at the occipital region gradually increases with change in size, dorsal and ventral margins of the body with thick pigmentation upto the 20th myotome; single chromatophore above anal opening; ventral margin with pigment spots towards caudal end; dark line of pigments in the lateral line on 14th to 19th myotome region which gradually extends to the caudal base; pigmentation in the region of air bladder well developed.

Pigmentation intensifies in juveniles. Body dense brown in colour from 7 mm onwards. Conspicuous change in body form noticed in 10 mm larva. Larva deep bodied and stubby with a pointed snout. Dorsal crest reduced in size. Caudal base remains free of any pigments. 2-3 patches of chromatophores above and below the lateral line.

In the 10.5 mm larvae meristic characters are as follows. D VII-I-20, A II- I 19, P-17, C 8+7. Total number of vertebrae 10+16 including urostyle. 6-8 dark blotches above lateral line and 3-5 faint ones below.

Behaviour, utilization: Moves in small schools and inhabits inshore waters. Feeds primarily on other fishes and small crustaceans. Young use specialized juvenile dentition to aggressively remove scales and epidermal tissue from other fishes. Spines of first dorsal and anal fins are venomous and capable of inflicting painful stings. Marketed fresh and dried salted.

Genus ***Caranx*** Lacepede

Adipose eye lids moderately to well developed, leaving anterior half of eyes exposed. Teeth in a band; in upper jaw, outer row enlarged; a single series in lower jaw with 2 to 4 anterior canines. Scutes prominent; breast rarely naked.

***Caranx sexfasciatus*** Quoy & Gaimard, 1824.

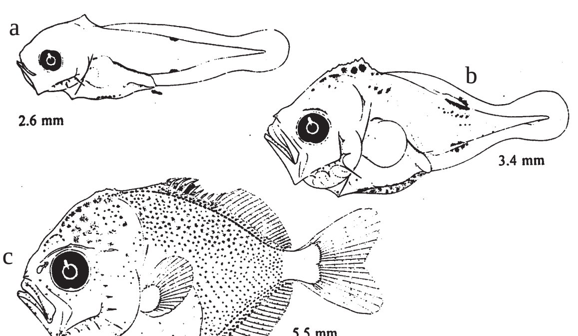



Fig. 24. *Caranx sexfasciatus* Preflexion larvae (a) 2.6 mm (b) 3.4 mm (c) Postflexion larva 5.5 mm (Moser, 1985)

Common name Big eye trevally

Total vertebrae 25; deep bodied; supraoccipital crest form at 3 mm; heavily pigmented preanal fin fold; strong pre-opercular spination, upto 6 below and 4 above elongate angle spine in posterior series and upto 1 above and 4 below angle in anterior series; single spine on post temporal and supracleithrum but none on supraocular or pterotic ridge.

Pigmentation: In the 2.6 mm larvae (Fig. 24.a) above gas bladder and gut, several on ventral margin of gut coil, one on terminal gut section anterior to anus, opposing blotches on dorsal and ventral margins of tail.

By 3.0 mm (Fig. 24.b), one to several above mid brain, one or more on supraoccipital crest, a pair at tip of snout, one on dorsum at mid trunk, streaks on dorsal and ventral margins of tail with lateral streak forming between them; on pre-anal finfold spreading on to trunk. By 4 mm, scattered over upper half of head and on trunk and tail except for caudal region; heavier laterally in region of tail streaks and streaks on dorsal and ventral body profiles extending on each side of dorsal and anal.

By 5.5 mm (Fig. 24.c), entire head and body covered except for caudal peduncle. By 14 mm caudal peduncle covered and bars beginning to form.

Distribution, utilization: Distributed throughout the Indo-west Pacific, juveniles occur in estuaries. Feeds primarily on fish and crustaceans. Marketed fresh and dried salted.

Genus ***Carangoides*** Bleeker

Body ovate to oblong, compressed. Adipose eyelids feebly developed. Fine teeth in jaws. Scales small not embedded in skin.Lateral line anteriorly with a feeble to moderate arch, posterior straight part with moderate armed scutes often weakly developed. First dorsal fin with 7 or 8 spines connected by a membrane; second dorsal and anal fins anteriorly only slightly elevated. No detached finlets behind dorsal and anal fins; anal fin base about equal in length to soft dorsal fin base. Pectoral fins long and sickle – shaped.

***Carangoides malabaricus*** (Bloch)

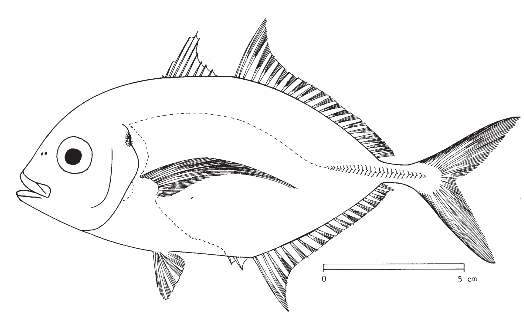



Fig. 25. *Carangoides malabaricus* (Fischer & Whitehead, 1974)

Common name Malabar trevally

Vernacular Vattapara

Body strongly compressed, ovate in young. Head profile steep forming a notch in front of eyes particularly when mouth is open. Two dorsal fins; first dorsal with one forward pointing spine and 8 normal spines; second dorsal with 1 spine and 20-23 soft rays. Dorsal and anal fin-bases equal. Anal fin with 2 detached spines followed by 1 spine and 17 or 18 soft rays.

Lateral line anteriorly forming a long low arch, twice as long as straight portion, the latter beginning under $12^{th}$ to $14^{th}$ soft dorsal rays, 25 to 28 feeble scutes on lateral line.

Distribution: Inhabits coastal waters; juvenile inhabit shallow inshore areas. Commercial catches vary in length from 10 to 15 cms.

Family **AMBASSIDAE**

Body oblong, compressed. Dorsal fin deeply divided before last spine with 7 or 8 spines and 8-11 soft rays; anal fin with 3 spines and 8-11 soft rays; last dorsal and anal rays split to their base; caudal fin forked with 15 branched rays. Vertebrae 10+14. Swim bladder present.

Genus ***Ambassis*** Cuvier, 1828

Scales large,  in longitudinal series. 1 or 2 rows of cheek scales.

***Ambassis gymnocephalus***  (Lacepede, 1801)

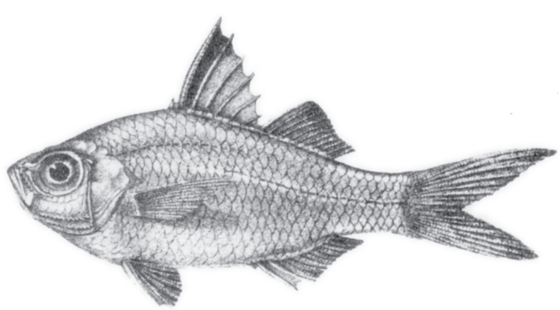


Fig. 26.1. *Ambassis gymnocephalus* (Day, 1971)

Common name  Bald glassy perchlet

Vernacular name  Nandan

D VII+I-10; A III 9-10; PII 12-14; V 1-5.

Lateral line interrupted, supra orbital ridge serrated, hind margin of preoperculum entire, head length about 2.8 times in standard length.

Newly hatched larvae measures 1.12 mm (Fig.26.2.a), yolk mass oval, its anterior end projecting in front of the head and hind end extending to the level of the fifth somite. Oil globule at the anterior end of the yolk mass with yellow and grey pigment spots. Twenty four myotomes. Longitudinal patches of black pigment spots along the dorsal and ventral borders of myotomes. About nine hours later after hatching,  larva is 1.56 mm long (Fig. 26.2.b).

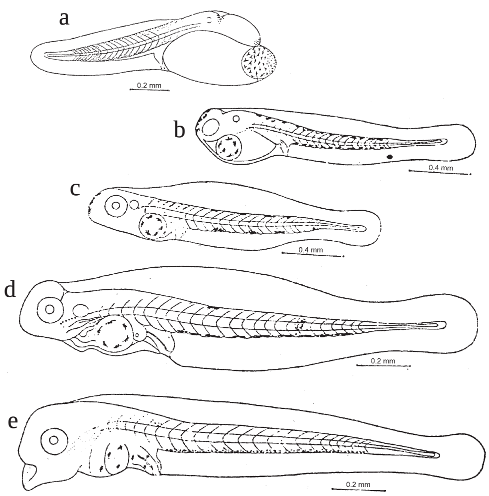



Fig. 26.2. *Ambassis gymnocephalus* Larvae (a) 15 hours after collection (b) 9 hours after hatching (c) 21 hours after hatching (d) 33 hours after hatching (e) 70 hours after hatching (Nair, 1957)

Yolk mass and oil globule considerably reduced so that the head projects in front of the yolk mass. Gut curved downwards not opening to the outside. Patches of yellow and grey pigments on the oil globule are replaced by the five or six branched pigment spots. Along the dorsal and ventral border, irregular row of branched pigment spots. 24 myotomes of which 18 are post-anal .

In about 21 hours of hatching, larva is 1.7 mm (fig.26.2.c).  Yolk reduced, black branching pigment cells reduced in number along the ventral border to four large branching pigment spots.  In larva after 33 hours of hatching (Fig. 26.2.d) pigment spots  spread out to form a more or less dark line along the ventral border.

70 hours after hatching (Fig.26.2.e) eyes quite conspicuous, yolk disappeared, oil globule reduced, pigmentation along the dorsal border of the myotomes and anterior border of the head disappeared.  Along the ventral border, pigment spots appear as a continuous row of prominent dark spots.

In juveniles of 1.65 cm, stellate chromatophores  found on the dorsal along the base of the fins and post-anal on the ventral body margin.

Distribution, utilization: Common in the backwaters and lagoons of India. Sundried and sold as dry fish.

Family  **LEIOGNATHIDAE**

Deep bodied, compressed rather small fishes with extremely protrusible jaws that point downwards. Scales small and are more or less absent over the head and breast. Bony ridges over the head that end in a nuchal spine. Anal long with three spines.

Genus **Leiognathus** Lacepede

Protracted mouth point downwards

***Leiognathus decorus*** (de Vis)

Syn. *Leiognathus brevirostris* (Valenciennes)

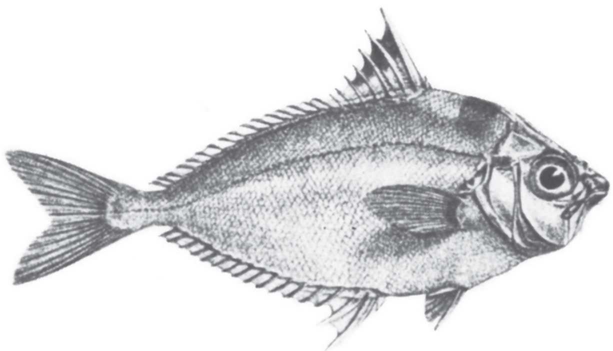


Fig. 27. *Leiognathus decorus* (Day, 1971)

Common name Short nose pony fish

Vernacular name Mullen

DVIII 16; A III 14; P i 17; V I 5

Brown blotch across nape; breast naked. Upper half of body with dark brown wavy to zigzag vertical lines.

Family **TERAPONIDAE**

Body oblong, slightly compressed. Preopercle serrate, opercle with about 6 spines, of which the dorsal one is the strongest and the longest.

Genus ***Terapon*** Cuvier, 1816

Post temporal bone serrate posteriorly, not covered by scales. Dorsal notched before last spine. Body with distinct dark stripes extending to caudal.

***Terapon jarbua*** (Forsskal, 1775)

Syn. *Sciaena jarbua* Forsskal, 1775
*Therapon jarbua* Chevey, 1932

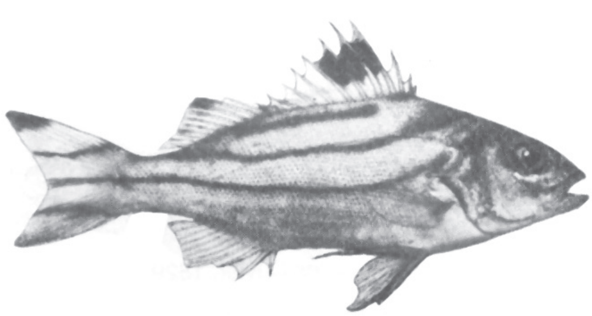


Fig. 28. *Terapon jarbua* (Smith, 1986)

D XI-XII, 9-11; A III, 7-10

Jaws equal, gape slightly oblique; preopercle strongly serrate, particularly at angle; lower opercular spine very long and strong, extending distinctly posteriorly. Spinous part of the fin strongly arched and deeply notched, first spine very short, 4th to 6th spines longest, and the penultimate spine about half the length of the ultimate. Four black downwardly curved stripes on body. Spinous part of the dorsal fin with a blackish band on upper portion of the fin membranes between third to sixth spine; soft part with membranes between first 3 rays tipped with black and membranes between 5th to 7th rays entirely black; caudal fin with median rays pigmented; both caudal lobes with dark tips and a transverse band.

Distribution, behaviour, utilization: Found in inshore waters, occurring in brackish and fresh waters. Feeds on fishes and invertebrates; commonly a scale eater. Marketed fresh and dried salted.

Family **SILLAGINIDAE**

Mouth small, terminal and protrusible. Two dorsal fins (little or no interspace), first consisting of 10-13 slender spines. Lower part of preopercle sharply angled inwards to meet that of the other side, thus forming the ventral surface of the head.

Genus ***Sillago*** **Cuvier**

Snout and head not depressed; second dorsal spine not elongate; eyes normal, 17 to 22 per cent of head length; air ladder present.

***Sillago sihama*** **(Forsskal)**

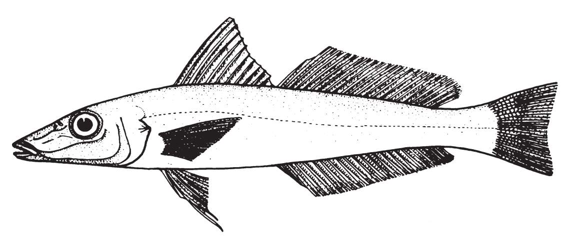


Fig. 29. *Sillago sihama* (Talwar & Jhingran, 1991)

Common name Silver sillago

D XI + I 20-23; 21-24; P 17; V I 5

Body elongate; gill rakers on lower arm of first gill arch 7 to 9. Air bladder with two very distinct post coelomic extensions.

In post-larvae measuring 6.5 mm length, the spinous first dorsal fin is not usually formed and a thick fin fold is visible; 20 and 21 soft rays develop in the second dorsal and anal fins respectively; caudal fin with 18 countable rays which are 3-4 segmented. As the 6mm larva grows to 20mm, pre-anal myomere count increases from 10 to 14 while, the post-anal myomere count decreases from 24 to 20 due to the gradual shifting of the position of the anus.

Pigmented spots (each one below each ray) line the base of the anal fin of the larvae; post-larvae measuring between 8-13mm often have 2 pigment spots at the anterior portion of the caudal peduncle.

Distribution: A nearshore species, penetrates estuaries for considerable distance, goes out to the sea for breeding.

Family **LUTJANIDAE**

Mouth moderate to large; jaws with more or less distinct canine teeth; vomer with small conical teeth; no enlarged pores on chin.

Larvae with 24 myomeres, pre-anal length approximately 50% total length, light pigmentation. The presence of long, smooth preopercular spines and the early development of spines in the dorsal and pelvic fins distinguish lutjanids from most similar larvae.

Genus ***Lutjanus*** Bloch

Body compressed, moderately deep to slender. Jaws with several enlarged canine teeth. Colour pattern largely consisting of yellow, pink or red.

***Lutjanus argentimaculatus*** (Forsskal)

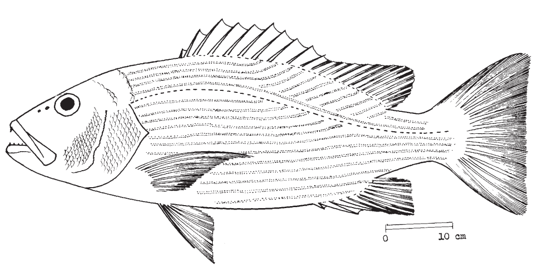



Fig. 30. *Lutjanus argentimaculatus* (Fischer & Whitehead, 1974)

Common name Mangrove red snapper

D X 13-14; A III 8-9

Head profile slightly convex; preopercle unnotched, its vertical and horizontal margins finely serrated. Caudal fin slightly emarginate. Longitudinal rows of scales above lateral line parallel to dorsal profile anteriorly, but appearing to rise obliquely under soft part of dorsal fin or under posterior part of spinous dorsal fin. Scale rows below lateral line horizontal.

Distribution: Juveniles usually inhabit mangrove and shallow water areas. Feeds mainly on crustaceans and fishes.

***Lutjanus russelli*** (Bleeker, 1849)

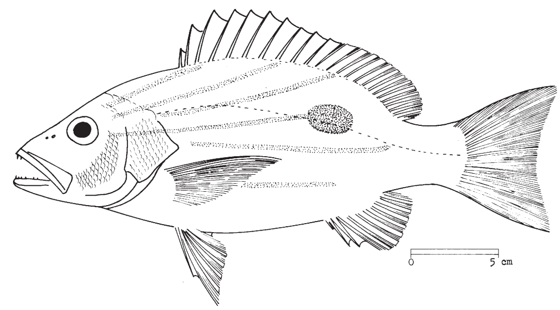



Fig. 31. *Lutjanus russelli* (Fischer & Whitehead, 1974)

Common name Russell's snapper

Head profile a little concave, inter-orbital space convex. Dorsal fin with 10 spines and 14 soft rays, anal fin with 3 spines and 8 soft rays. Caudal emarginate. Longitudinal rows of scales above lateral line appear to rise obliquely to dorsal profile, those below lateral line horizontal. A dark, variable blotch above lateral line below junction of spinous and soft parts of dorsal fin. About 8 golden/light brown lines on body, lower ones horizontal and upper ones rising obliquely to dorsal profile.

Distribution: Inhabits shallow waters; juveniles found in mangrove areas; feeds on bottom living invertebrates.

Family **GERREIDAE**

Two nostrils on each side of head. Dorsal fin inserted in anterior half of body; anterior rays of soft dorsal and anal fins not elongate. Lateral line complete. Mouth strongly protractile. Head scaled, no nuchal crest; gill membranes free from isthmus; branchiostegal rays 6.

Genus ***Gerres*** Cuvier

Anal fin with 3 spines and 7 soft rays. Dorsal fin with 9 spines.

***Gerres filamentosus*** Cuvier

Common name Whiptail silver-biddy

D IX 10-11; A III 7; P i 14; V I 5

Body deep and compressed, its depth 2 to 2.5 times in standard length. Predorsal distance equal to or less than depth of body.

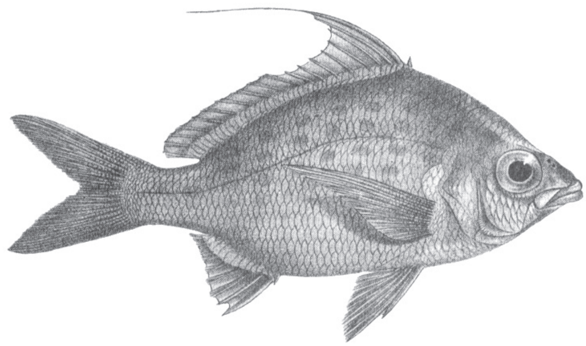


Fig. 32. *Gerres filamentosus* (Day, 1971)

Second dorsal spine laterally compressed, produced into a filament whose tip extends past level of first anal spine. Scales moderate; lateral line with 44 to 47 scales.

Pigmentation: 7 to 10 vertical series of ovoid bluish spots on upper portion of sides. Pectoral, pelvic, caudal and anal fins dusky; dorsal fin hyaline, except for end of filamentous spine which is black.

Distribution: Inhabits coastal waters, enters brackish waters.

***Gerres poieti*** Cuvier

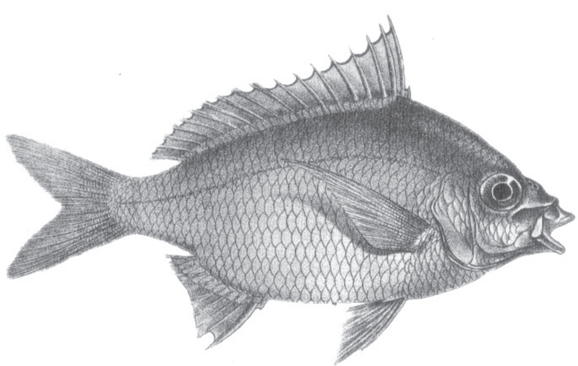


Fig. 33. *Gerres poieti* (Day, 1971)

Common name    Strong spine silver-biddy.

Body deep and fairly compressed, its depth 2.1 to 2.3 times in standard length.

D X 9; A III 7;P  i 4;V I 5

Second dorsal spine shorter than head; second anal spine exceptionally robust, often as long as anal fin base. Scales moderate; lateral line with 38 to 40 scales; 4 scale-rows between lateral line and base of 5th dorsal spine.

A fine black line outlining margin of membrane of dorsal fin; tips of first few rays of anal fin and trailing edge of caudal fin dusky.

Distribution: Inhabits estuaries and coastal lagoons, also coastal waters.

Genus ***Pentaprion*** Bleeker

Body compressed, oval. Anal longer than soft part of dorsal.

***Pentaprion longimanus*** (Cantor)

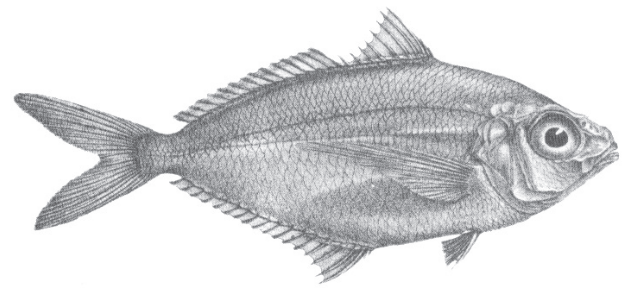


Fig. 34. *Pentaprion longimanus* (Day, 1971)

D IX-X, 14-15; A V-VI, 12-14

Pelvic branched rays 13-14. Readily distinguished by the large number of radials in the long anal fin.

Family **SCATOPHAGIDAE**

Body deep and strongly compressed; greatest body depth more than half of total length. Anal fin with 4 spines.

Genus ***Scatophagus*** Cuvier

Body squarish in outline, with triangular head projecting anteriorly. Head small, mouth small, not protractile; jaw teeth in several rows. Pectoral fins relatively small. Caudal fin rounded in juveniles.

***Scatophagus argus*** (Linnaeus)

Syn. *Chaetodon argus*

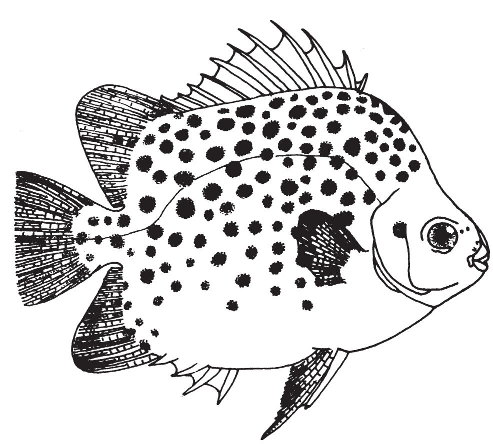


Fig. 35. *Scatophagus argus* (Talwar & Jhingran, 1991)

Common name       Spotted scat

D XI 16-18; A IV 14-15; P 16-17; V I 5

Body quadrangualar, compressed. Head profile rising steeply to nape. Snout and interorbital space rounded. Dorsal fin deeply notched. Colour in life variable; young fishes of 2 cm dark in colour, finest colouration attained in fishes of about 5-6 cm in total length. Uniform greenish/bluish silvery with numerous dark spots mainly confined to upper portion of sides.

The body of the juvenile is somewhat oval in shape and very compressed; head large and possess bony plates; strong shoulder spine (supra scapular spine) present; spinous dorsal fin bright purple in colour having a brownish tinge posteriorly; black chromatophores and red pigmented cell groups are present on the body.

Distinct red pigmented cell groups in five locations along dorsal profile: at the nape, spinous dorsal origin, junction between the spinous and soft dorsal, on the middle of the soft dorsal, and at the end of the soft dorsal/beginning of the caudal peduncle.

Distribution : Inhabits harbours, natural embayments, estuaries, mangroves and the lower reaches of freshwater rivers.

Family **MUGILIDAE**

Robust body, abdominal pelvic fins, widely separated short-based dorsal fins, lack of spines on the opercular series bones, position of vent almost at the middle region. Post larval development characterised by dense pigmentation.

Genus ***Mugil*** Linnaeus

Hind tip of maxilla not curved below tip of premaxilla; adipose eyelids well developed.

***Mugil cephalus*** Linnaeus, 1758

$D_1$ IV, $D_2$ I 8; A III 8

No spines on head or pectoral girdle. Robust form. Heavily pigmented throughout development.

Pigmentation: Late yolk-sac larvae - Anteriorly on both jaws; ventral to mid and hind brain; in optic capsule, heavy on dorsum from mid brain to myomere 18, light dorsolaterally on trunk and tail to myomere 18, extending up onto sides of tail; few on notochord tip dorsally.

Pre-flexion larva - Increasing on all areas except last 4 myomeres and lower half of head, lightly pigmented.

Flexion larva - Gradually spreading, only last 1-2 myomeres and hypural area unpigmented, pigmentation denser on dorsal and ventral margins and lateral mid line.

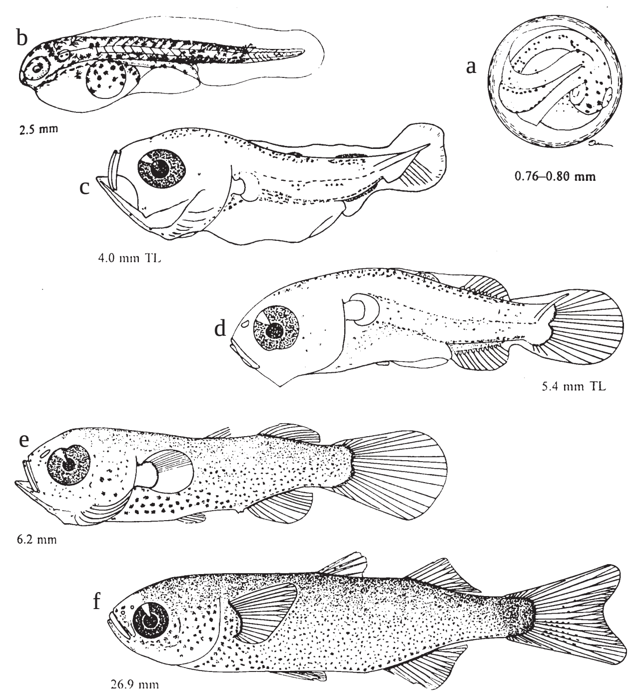



Fig. 36. *Mugil cephalus*
(a) Egg, 0.76-0.80 mm (b) Yolk-sac larva, 2.5 mm (c) Late preflexion larva, 4.0 mm TL; (d) Late flexion larva, 5.4 mm TL; (e) Postflexion larva, 6.2 mm TL; (f) Pelagic juvenile, 26.9 mm SL (reproduced from Moser, 1985)

Post-flexion larva - Uniformly covered by 6 mm except distal margin of fin bases. Transformation length between 7.5 and 12.0 mm. Hypural area and proximal part of caudal pigmented, silvery begining ventrolaterally on abdominal area by 8.0 mm.

Juvenile 26.9 mm (Fig.36.f) vertebrae 24; precaudal 11-12, caudal 12-13.

Distribution: The most common mullet in the estuaries of India.

Genus ***Valamugil*** Smith

No fleshy lobes between arms of lower jaw.

Lower third of upper lip without papillae.

Hind tip of maxilla curved down below tip of premaxilla.

Tip of maxilla hidden beneath tendon when mouth is closed; hind margin of scales digitated.

***Valamugil speigleri*** (Bleeker)

$D_I$ IV, $D_2$ 1 8; A III 9; P 16; V i-5.

Adipose eyelids well-developed, covering most of iris.

Minute villiform teeth on both lips, absent on vomer and palatines; lips thin, lower lip with a high symphysial knob. PreorbitaI fairly wide, filling space between lip and eye, notched on anterior edge.

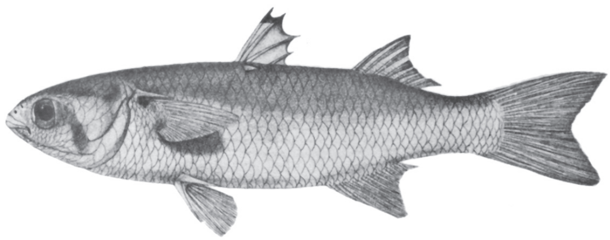


Fig. 37. *Valamugil speigleri* (Day, 1971)

First dorsal fin inserted nearer to snout tip than to caudal fin base; second dorsal fin origin on vertical through end of anterior-quarter of anal fin base. Pectoral fins slightly shorter than head length, reaching vertical through second dorsal spine. Pectoral axillary scale long, 32 to 34% of pectoral fin length; second dorsal and anal fins densely scaled; scales in lateral series 37 to 40.

Pectoral fins with a black axillary spot. First dorsal fin margin black; other fins dusky.

Genus **Liza** Jordan and Swain

No fleshy lobes between arms of lower jaw. Lower third of upper lip without papillae. Hind tip of maxilla curved down below tip of premaxilla.

Hind margin of scales not digitated; tip of maxilla visible when mouth is closed.

***Liza subviridis*** (Valenciennes)

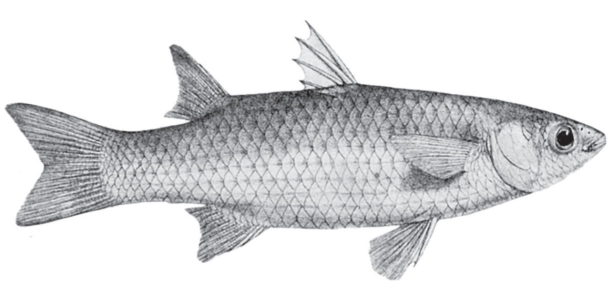


Fig. 38. *Liza subviridis* (Day, 1971)

Common name Greenback mullet

$D_I$ IV, $D_2$ i 8-9; A iii 9; P 16; V i 5

Adipose tissue covering iris.

Teeth labial, several rows of fine teeth on upper lip, one row of viliiform teeth on lower lip.

Preorbital narrow, filling only 3/4 of space between lip and eye, anteriorly notched.

First dorsal fin inserted nearer to caudal fin base than to snout-tip, or midway between them; second dorsal fin origin on vertical between anterior-third and half of anal fin base.

Pectoral fin length 74 to 76% of head length. Pectoral axillary scale rudimentary or absent; second dorsal and anal fins densely scaled; scales in lateral series 27 to 32; 11 scales in transverse series.

Caudal fin edged with black.

Distribution: Inhabits coastal waters, including estuarine areas.

***Liza tade*** (Forsskal)

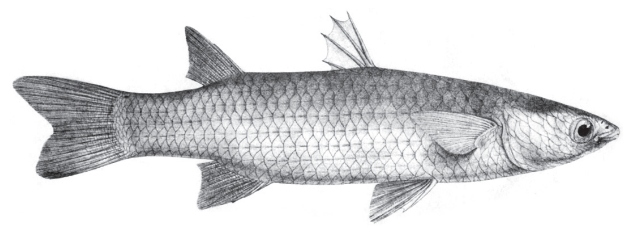


Fig. 39. *Liza tade* (Day, 1971)

Common name Tade mullet

$D_1$ IV, $D_2$ I 8; A III 9; P 17; V I 5

Body slender and elongate. Head wide, much depressed and pointed, its length 19 to 25% of standard length. Preorbital wide. First dorsal fin inserted nearer to snout tip than to caudal fin base (but midway in young ones); second dorsal fin origin on vertical through posterior half of anal fin base. Pectoral fin length 75 to 79% of head length, inserted slightly below horizonal line through centre of pupil; pelvic fin origin nearer to anal fin origin than to tip of snout. Caudal fin forked. Pectoral axillary scale rudimentary or absent; second dorsal and anal fins densely scaled; scales in lateral series 30 to 35.

Head of juveniles dorsoventrally more flattened, broader and somewhat pointed towards the snout. Second dorsal fin originates vertically through the posterior half of the anal fin base. Larvae measuring 1.7mm have pigments along the ventral aspects of the post-anal region and above pectoral region, a few minute spots at the caudal end.

Distribution : Indo-west Pacific. Primarily marine, but entering estuaries and back waters.

Genus **Sicamugil** Fowler

Spine on operculum above pectoral fin base.

Adipose eye lids absent.

Lips thin; lower lip with a symphyseal knob; no distinct teeth on jaws and palatines.

***Sicamugil hamiltonii*** (Day)

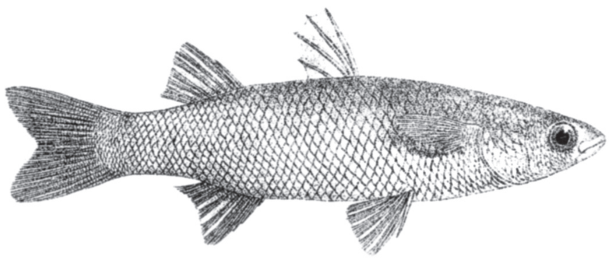


Fig. 40. *Sicamugil hamiltonii* (Day, 1971)

$D_1$ IV, $D_2$ i 8; A iii 9; P 12-14; V i 5

Dorsal fin inserted near to base of caudal fin than to tip of snout. Anal fin origin anterior to vertical from second dorsal fin origin.

Scales 43 to 47 in longitudinal series.

Colour: Back grayish, flanks and belly silvery shot with gold.

Family **CICHLIDAE**

Body moderately deep and compressed. Single nostril on each side of snout. Dorsal fin with 12 to 22 spines and 8 to 23 soft rays; anal fin with 3 to 16 spines and 6 to 24 soft rays. Lateral line in two sections, anterior one curved, parallel to dorsal profile, posterior one straight, along posterior part of the body.

Genus ***Etroplus*** Cuvier

Anal fin with 12-16 spines.

***Etroplus suratensis*** (Bloch)

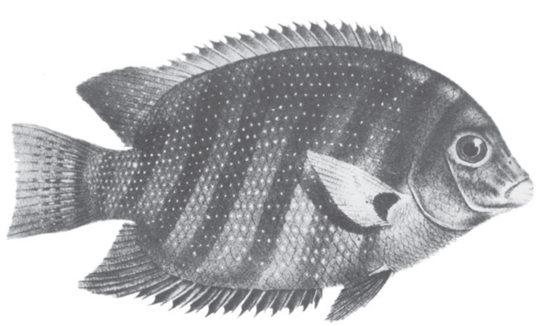


Fig. 41. *Etroplus suratensis* (Day, 1971)

Common name Banded pearl spot

Vernacular name Karimeen

D XVIII – XIX, 14-15; A XII – XIII, 11-12

Body very deep, short, oval and strongly compressed. Eyes large, its diameter 3 to 4 times in length of head. Mouth small. Caudal fin slightly emarginate. Scales weakly ctenoid; lateral line interrupted at $16^{th}$ or $18^{th}$ scale; 35 to 40 scales in longitudinal series. Colour light green with six to eight not very prominent vertical bands (first across occiput, last across base of caudal fin) most of scales above lateral line with a central white pearly spot. Pectoral fins yellowish with a black blotch at its base.

Distribution, utilization: Inhabits brackish waters and mouths of rivers; often open sea. Thrive well where luxuriant growth of aquatic vegetation is available. Attain 10-12 cm and 113 g in one year in ponds. An excellent delicious fish, especially when large.

***Etroplus maculatus***(Bloch)

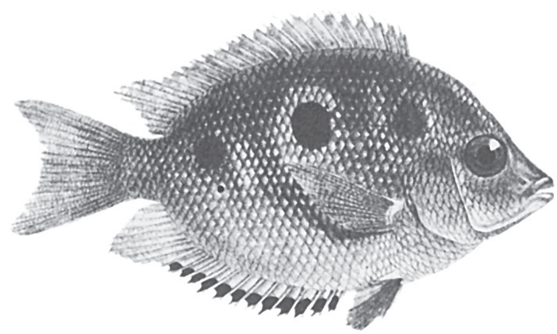


Fig. 42. *Etroplus maculatus* (Day, 1971)

Common name Spotted etroplus

Vernacular name Pallathi

D XVII-XX 8-10; A XII-XV 8-9; P i 15-16; V i 5

Body disc-shaped, very deep and strongly compressed.

Eyes large, the diameter about 3 times in head length. Mouth small; teeth villiform in 2 or 3 rows on jaws.

Caudal fin lunate. Scales weakly ctenoid; lateral line interrupted, with about 35 scales in longitudinal series.

Colour: Numerous horizontal lines of deep golden spots; three large, round black blotches on flanks, middle blotches largest and darkest. Spinous dorsal fin with several brown and yellow spots; pelvic fins deep black; anal and caudal fins yellowish, the former with a deep black border while the latter fin is with a reddish edge.

Distribution: Inhabits fresh and brackish waters along coastal areas of peninsular India.

Family **POLYNEMIDAE**

Body moderaly elongate, somewhat compressed. Eyes with adipose tissue. Mouth subterminal, the overhanging snout conical and prominent. Two widely separated dorsal fins. Pectoral fins divided into two sections, upper normal with rays attached and lower with 4 to 7 long unattached (free) rays; pelvic fins subabdominal.

Genus ***Eleutheronema*** Bleeker

Lower lip absent except towards the mouth corners; teeth extending on exterior part of jaws. Pectoral fins inserted low on body, upper part of its base well below middle line of body; a sharp fold of skin projecting down or forward from lower end of base of pectoral fin. Lateral line nearly straight.

***Eleutheronema tetradactylum*** (Shaw)

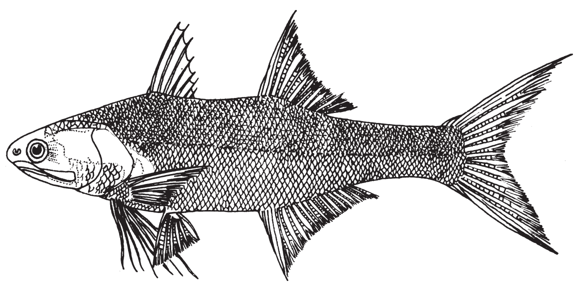


Fig. 43. *Eleutheronema tetradactylum* (Talwar & Jhingran, 1991)

Common name Fourfinger threadfin

$D_1$ VIII, $D_2$I 13-15; A II 15-17; P 17 + iv; V I 5

Pectoral fin in two parts, upper part with all rays unbranched and lower part with 4 free filamentous rays. Caudal fin forked, with lobes equal.

In larvae measuring around 7.5 mm in length, the mouth is large with prominent upper and lower jaws; cleft of the mouth located slightly towards the ventral profile of the head. Pectoral fins are not yet fully developed; spinous portion of the anal fin is traceable to some extent but not the spinous portion of the dorsal fins; caudal fin is somewhat truncated. Pre-anal myomere count increases and the corresponding post-anal myomere count decreases within the given range due to the posterior shifting of the anus. A black pigment spot is present at the nape region of the larvae and at times in the upper jaw.

Distribution : Inhabits sandy shores and muddy estuaries. Enters the estuary for breeding when the salinity of the water starts rising, ascends higher up the rivers than any of the other polynemids. Young ones are found in abundance in the lower reaches of the estuaries and the fishery of this species is sustained by the juveniles.

Genus ***Polynemus*** Linnaeus

Lateral line with its anterior part rising in long, low curve; pectoral fins inserted high on body, upper part of its base in level with midline of body or higher; without a sharp pectoral fold extending down from lower part of base of pectoral fin to cover bases of one or more of pectoral filaments; free pectoral filaments 7 or 8, very long.

***Polynemus indicus*** (Shaw)

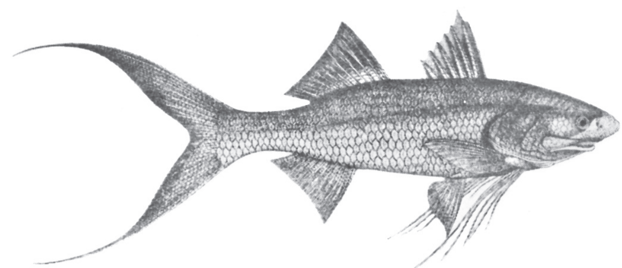


Fig. 44. *Polynemus indicus* (Munro, 1955)

Common name Indian tassel fish

D VIII; I, 13-14. A II-III, 11-12. P (2-3)+(12)+5

First 2-3 pectoral rays simple, remainder branched. Pectoral filaments reach almost to anal origin. Second dorsal originates in front of anal. Swim-bladder thick and very long. Body golden, much darker above, with faint lines along scale rows. Fins yellowish.

Larvae of 21st day after hatching attained a length of 22.4 mm and had become completely opaque. Dorsal fins formed; caudal fin distinctly forked, pelvic fin appeared as small buds; lower lobes of the pectoral fin was very conspicuous. Patches of dark black pigments noticed over the eyes and in the head region.

Larvae of 40th day of 31.8 mm length exhibited all adult characters. The young fish was black purplish at the back and the abdomen was silvery white dashed with gold.

Distribution : Inhabits shallow sandy inshore areas; entering fresh waters during breeding seasons.

Family **GOBIIDAE**

Body elongate with scales; pelvic fins united, forming a disc.

Genus ***Acentrogobius*** Bleeker, 1874

Scales large, ctenoid; gill opening to just below pectoral base; pelvic a disc.

***Acentrogobius audax*** Smith, 1959.

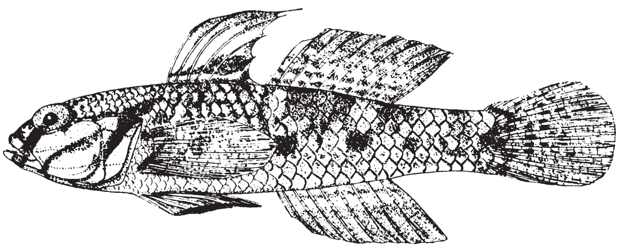


Fig. 45. *Acentrogobius audax* 5.5 cm TL (Smith, 1986)

Common name Mangrove goby

D VI + I, 9; AI, 9; P 17

No opercular scales. Caudal peduncle with curved dark bar followed by a dark bar on caudal base.

Distribution: Tropical species found on mud and sand bottoms.

Genus ***Favonigobius*** Whitley, 1930

Gill opening extending to below mid-operculum; no scales on opercle or pre-opercle; ventral a disc.

***Favonigobius reichei*** (Bleeker, 1953)

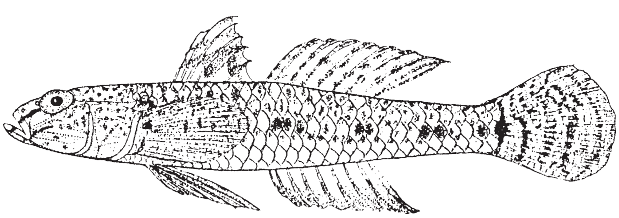


Fig. 46. *Favonigobius reichei* 5 cm TL (Smith, 1986)

Common name Tropical sand goby

D VI + I, 8; AI 8; P16

Snout gently sloping; bar from eye to upper jaw at an angle of about $40^o$ with body axis.

Body with numerous small spots; mid side with 4 or 5 slightly enlarged groups of black spots, last spot on peduncle paired; median fins spotted.

Genus ***Glossogobius*** Gill, 1862.

Snout elongate; head depressed; gill opening from below rear of preopercle to below eye. Pelvic fins form a disc. Scales ctenoid; operculum and cheek naked.

***Glossogobius callidus*** (Smith, 1937)

Common name River goby

D VI + I, 8-10; AI, 7-9; P 14-19; lateral scales 28-32.

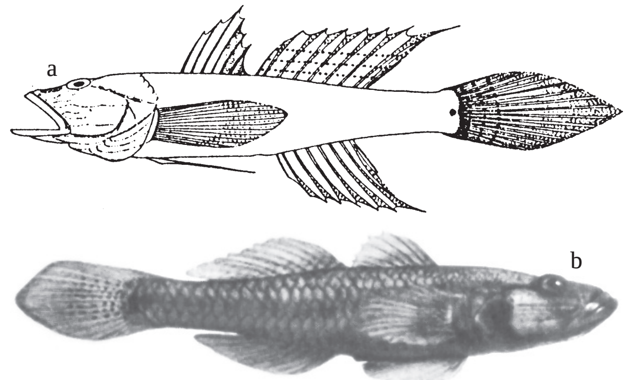



Fig. 47. *Glossogobius callidus* (a) 9 cm (b) 10.5 cm (Smith, 1986)

Dorsal with some spotting, but spots not prominent along front edge of $2^{nd}$ dorsal; a thin dark stripe from eye to upper lip; enlarged vertical bar or spot at caudal base.

***Glossogobius giuris*** (Hamilton -Buchanan)

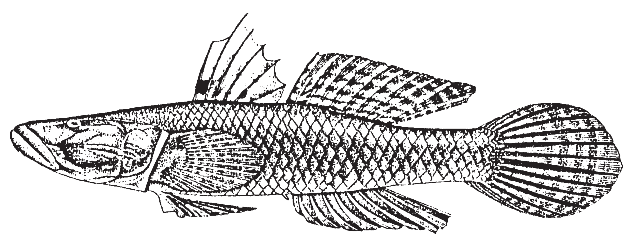


Fig. 48. *Glossogobius giuris* 23.5 cm (Smith, 1986)

D VI; I, 8-9; A 1, 8;

Lateral row scales 30-34; 16-22 predorsal scales.

Papillae pattern: lines 9-10 in three or more rows, lines 15 and 16 separated, lines 17 and 18 separated, lines 20, 21 and 22 unbranched.

Dorsal with small spots forming longitudinal stripes, spots darkest along spine of $2^{nd}$ dorsal.

Genus ***Awaous*** Valenciennes

Head elongate, broader than deep; interorbital space broad. Small finger like flaps on shoulder girdle. Dorsal fins close to each other; all dorsal spines thin and flexible, pelvic fins united and form disc. Scales on body ctenoid.

***Awaous gutum*** (Hamilton-Buchanan)

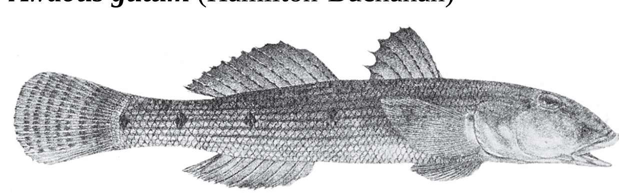


Fig. 49. *Awaous gutum* (Day, 1971)

DVI+I 10; A I 10; P i 15-17

Eyes fairly small, its diameter 4.5 to 5 times in head.

Scales on operculum, breast and belly cycloid, on occiput ctenoid; 51 to 58 scales in longitudinal series. Predorsal scales 17 to 24.

Colour: Head with irregular blackish spots and two longitudinal blackish streaks from eye to maxilla; body with blackish spots; a blackish spot on base of caudal fin and also on base of pectoral fin. Fins yellowish; first dorsal fin with 3 or 4 and second dorsal fin with 5 or 6 longitudinal dark streaks.

Fishery information: Inhabits rivers and estuaries. This species attains a length of 15 cm SL; of no interest to fisheries.

Family **TRYPAUCHENIDAE**

Body eel-like, pelvic fins united, eyes very small. Pouch like cavity in opercular region.

Genus ***Trypauchen*** Valenciennes

Body elongated and compressed. Head compressed with a bony median crest on occiput. Eyes minute. Mouth very oblique. Lower jaw prominent. Dorsal and anal fin continuous, confluent with caudal fin. Pectoral fins small; pelvic fins small, completely united forming a disc. Caudal fin pointed. Scales small, cycloid.

***Trypauchen vagina*** (Bloch & Schneider)

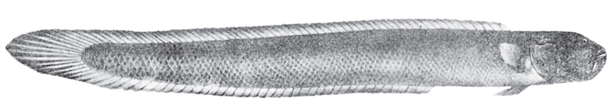


Fig. 50. *Trypauchen vagina* (Day, 1971)

Common name Burrowing goby

D VI 39-47; A I 40-46; P 15-17

Body elongate and compressed. Teeth in several rows pointed, outer row enlarged. Dorsal and anal fin continuous. Scales small, 80-100 in longitudinal series; head naked.

Distribution, utilization: Inhabits seas and estuaries. Attains a length of 22 cm. This species is of no interest to fisheries.

Suborder **GOBIODEI**

Head with mucous canals and open pores. Mouth terminal bordered by protractile premaxillaries. Spinous dorsal fin with 1 to 8 flexible spines; anal fin similar to soft dorsal fin without or with a feeble spine. Pelvic below pectoral fins with one spine and 4-5 soft rays. Vertebrae 25-35.

Family **ELEOTRIDIDAE**

Body oblong to elongate; pelvic fins separate, bases close together. Mouth never inferior, teeth small and conical, in several rows. Two dorsal fins; first fin with 6 flexible spines, second fin short based, rays I 8 to 19. Anal fin inserted just behind dorsal fin origin, rays I 6 to 19. Caudal with 15 or 17 rays. Pelvic fins I 5, widely separated. Body scaled, no lateral line on body.

Genus ***Butis*** Bleeker

Preopercle angle without spines; no teeth on vomer; bony ridge above eye. Jaws and snout elongate, snout flat, about twice eye diameter; lower jaw projecting; head flat.

***Butis butis*** (Hamilton – Buchanan)

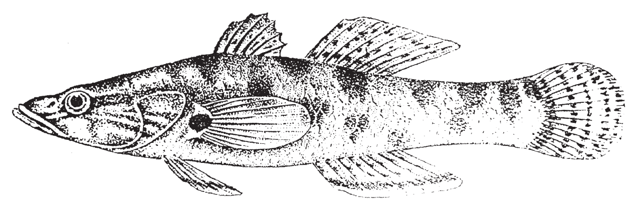


Fig. 51. *Butis butis* (Talwar & Jhingran, 1991)

Common name Duck bill sleeper

$D_1$ VI, $D_2$ I 8; AI 8; P 18-20; V I 5

Blackish, lighter below, with several dark lines. Caudal fin black with a light margin dorsally. Pectoral fin base with one or two black spots.

Distribution, utilization: Carnivores, often sluggish fishes of shallow waters from marine to fresh water conditions, especially estuaries. Of no interest to fisheries.

Family **TRICHIURIDAE**

Body extremely long, compressed and ribbon like. Mouth large, lower jaw projecting. Dorsal fin low and long based, inserted shortly behind eyes, its anterior spinous part shorter than posterior soft portion; tail tapering to a point. Scales absent; lateral line single.

Genus ***Trichiurus*** Linnaeus

Pelvic fin absent; pectoral reaching lateral line; head profile not convex.

***Trichiurus lepturus***, Linnaeus

Common name Ribbon fish

D III, 124-138; A II, 105-108; P 10-12

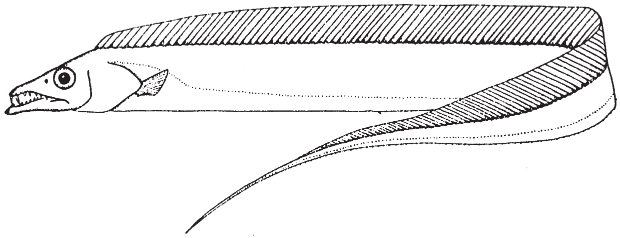


Fig. 52. *Trichiurus lepturus* (Smith, 1986)

Head with a prominent crest. Lower rear margin of gill cover concave. Small cartilagenous knob on tip of each jaw. Anal not apparent, with 2 minute triangular spines and about 105 soft rays reduced to minute spinules.

Juveniles (59-240 mm length) with following fin formula : D128; A 98; P 10-11. Post-anal myomeres more than 100. Single ventral pigment patch on tail, series of melanophores along dorsal margin.

In yolk sac larvae, few scattered pigments from tip of snout to above midbrain, few on gut; large ventral patch posteriorly on tail, extends well onto finfold. Dorsal series of pigments beginning at dorsal origin by 6.5 mm, spreading anterior above hindbrain by 7.4 mm and caudad to ca. 90% body length by 20mm; few pigments at tip of lower and upper jaws after 16mm; series on dentary; 1-2 ventrally on basihyal; anteriorly on gut.

Distribution: Often benthopelagic on continental shelf and slope. Inhabits coastal water and estuaries.

Family **SCOMBRIDAE**

Small or relatively large scales, larger on cheeks; 5-7 detached finlets. Includes mackerels, tunas, seerfishes, billfishes etc. Salient features of Scombroid larva are their short truncated shape, large head relative to the rest of the body and presence of strong preopercular spines and the sharply pointed snout with well developed teeth on jaws.

Genus ***Rastrelliger*** Jordan & Starks, 1908

Adult body depth greater than head length. Absence of preopercular spines identifies the larvae and post larvae of *Rastrelliger* from other scombroids.

***Rastrelliger kanagurta*** (Cuvier, 1816)

Common name Indian mackerel

Vernacular name Ayala

D X; 12; 5 A 12; 5

Body moderately deep, its depth at margin of gill cover 4.0-4.8 times in standard length.

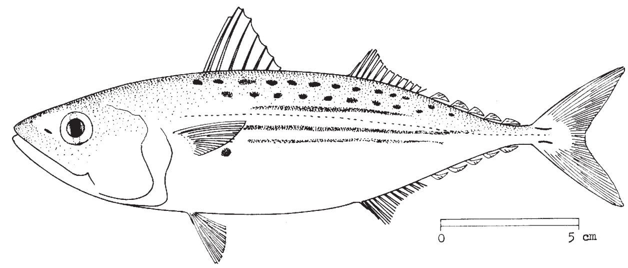



Fig. 53.1. *Rastrelliger kanagurta* (Fischer & Whitehead, 1974)

Head longer than body depth. Well developed adipose eyelids. Second dorsal and anal fin followed by 5 finlets.

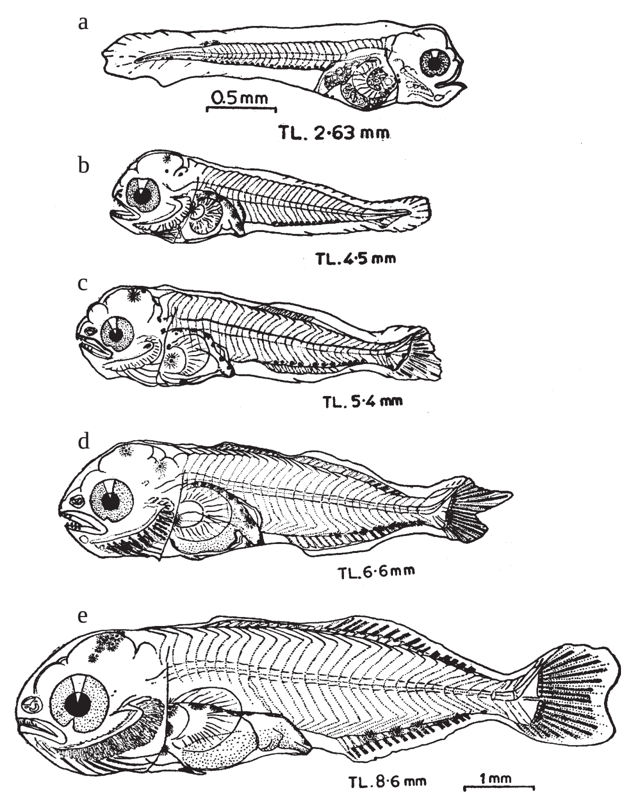



Fig. 53.2. Camera Lucida drawings of larvae of *Rastrelliger kanagurta* (Silas, 1974)

Short bodied larva with 31 myomeres, 10 of which are pre-vent in position. Number of myomeres are variable until the full complement is formed in 2.63 mm larva (Fig.53.2 a). Myomeres grow obliquely with zig zaging in most of the segments by about 5.4 mm. The head, especially the mouth with the more prominent lower jaw, the large eyes and the short intestine are characteristic. The upper jaw and snout region appears 'pug-nosed'. Disposition of melanophore pigmentation is characteristic. A row of about 30 melanophores present from behind the base of the larval pectoral fin to close to the end of the urostyle along the ventral side. This number decrease with growth and in older larvae, the post vent row of melanophores vary from 11 to 14.

In larvae above 4 mm, the post vent melanophores are absent in the first four myomeres behind the vent. Stellate chromatophore on the occipital region of the head after the hypural plates are formed. Chromatophores along the dorsal part of the peritoneum and ventral side of abdomen are diffuse. On the caudal region, a melanophore present at the base of the urostyle and two on the dorsal margin of two of the lower hypural plates (Fig. 53.2 a-c). Stellate chromatophore at the base of the larval pectoral fin, a dark chromatophore above the stomach and another on the posterior border of the intestine at the place where it bends downwards to the vent, present.

Family **STROMATEIDAE**

Ovate, compressed body covered with moderately small scales. Head mostly scaly. Lateral line simple and complete. Moderately small mouth with weak jaws and a single series of slender pointed teeth. Dorsal with a distinct spinous portion but spines more or less wholly embedded in the skin.

***Pampus chinensis*** (Euphrasen)

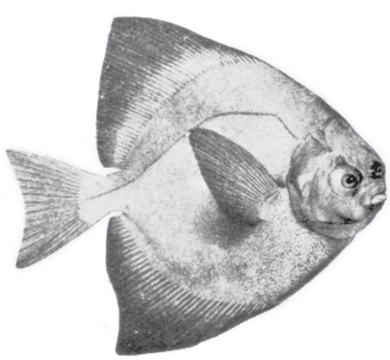


Fig. 54. *Pampus chinensis* (Munro, 1955)

Common name Chinese pomfret

D 43-50; A 39-42; P 23-25

Posterior part of dorsal comprising rays of gradually decreasing height after 16$^{th}$. Anal similarly concave along its border. Caudal emarginate in young, more slightly forked in adults.

Body of the juveniles is compressed and deep, terminal mouth; gill opening looks like a vertical slit. Stellate pigment is at times present on the head; preoperculum ridge is not yet discernible at this stage; dorsal profile between the snout and dorsal fin origin slightly depressed. Blade-like spines absent prior to the dorsal and anal fin origin. Pelvic fins absent.

Distribution : Inhabits waters over muddy bottoms of the continental shelf ; down to 100 m.

***Pampus argentius*** (Euphrasen)

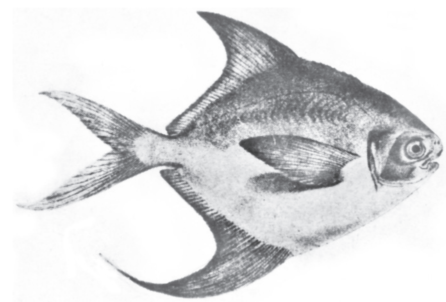


Fig. 55. *Pampus argentius* (Munro, 1955)

Common name Silver pomfret

D V-IX; I, 37-43; A I, 38-43; P 23-26

Posterior part of dorsal comprising rays of equal length. Blade like spines present anterior to dorsal and anal fins; caudal fin deeply forked with longer lower lobe; medians fins are not very broad; dorsal and anal fins originate well behind the pectoral fin origin; groove like pigmentation at times present near the nape.

Distribution : Inhabits waters over muddy bottoms, down to 100 m.

Family **SIGANIDAE**

Relatively short, round snout, seven spines in the anal fin, two spines in the pelvic fins, a forward -pointing spine in front of the dorsal fin and no spines laterally along the tail.

***Siganus javus*** (Linnaeus)

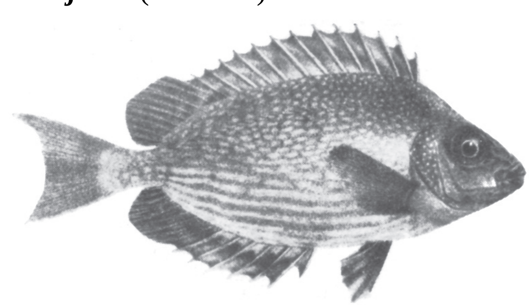


Fig. 56. *Siganus javus* (Day, 1971)

D XIII, 10; A VII, 9

Common name Streaked spinefoot

Back dark bronze, paler below, with blue spots on head and upper sides; blue undulating lines on mid and lower sides.30-35 scale rows between lateral line and base of dorsal spines. Body depth 2.0-2.3 times in standard length.

Distribution: Indonesia, India, Thailand, Taiwan, New Guinea, Gulf of Oman.

Order **PLEURONECTIFORMES**

Flattened body shape; eyes present on one side of body only.

Genus ***Solea*** Quensel 1806.

Larval finfold sometimes show stellate pigments. During post larval development there is a metamorphosis involving the shifting of the left eye to the right side.

***Solea heinii*** Steindachner 1902

Possess a hump at the posterior dorsal aspect of the skull in early stages.

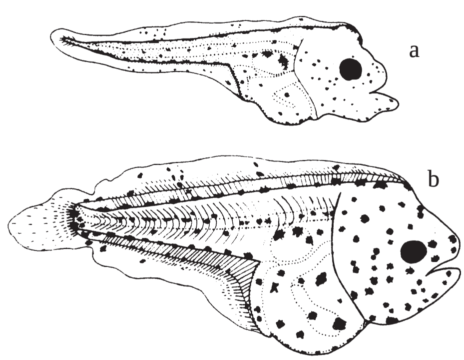



Fig. 57. *Solea heinii* larvae (a) 2.7 mm (b) 3.2 mm standard length (Balakrishnan & Devi, 1974)

A circular intestinal coil which soon transforms into an oval one and fills the space between the cleithrum and intestine; a much forwardly bent distal half of the cleithra. Eyes symmetrical and black; swim bladder present. A snout which is almost equal to or exceeds the horizontal diameter of the eye. Dense dark brown pigment spots or patches all over the body. 32 myotomes in 2.5 mm larva, and 33 in 2.7 mm stage. 37 vertebrae including urostyle visible in 3.2 mm larva. In 3.2 mm larva, median fins are continuous but remain separate from caudal, 68 dorsal and 55 anal rays, hypurals well developed, urostyle strongly deflected dorsalward, 14 caudal rays visible.

*S.heini* differs from *S.ovata* in the presence of a hump, number of fin rays, pattern of pigmentation and length of larvae at different stages.

Genus ***Cynoglossus*** Hamilton – Buchanan 1822

Embryo pigmented with stellate chromatophores on its body and larval fin fold.A tentacle develops dorsal to the head in early postlarval stage which is the first dorsal ray followed by the development of the second to a few more rays in further stages.

***Cynoglossus puncticepes*** Richardson, 1846.

Larvae comparatively small. Presence of elongated rays at the anterior end of the dorsal fin fold, development of ventral fin at a very early stage, number of vertebrae 49, metamorphosis taking place when the larvae attain a length of 4.3 to 4.9 mm are the characteristics that distinguish *C.puncticeps* from other cynoglossids.

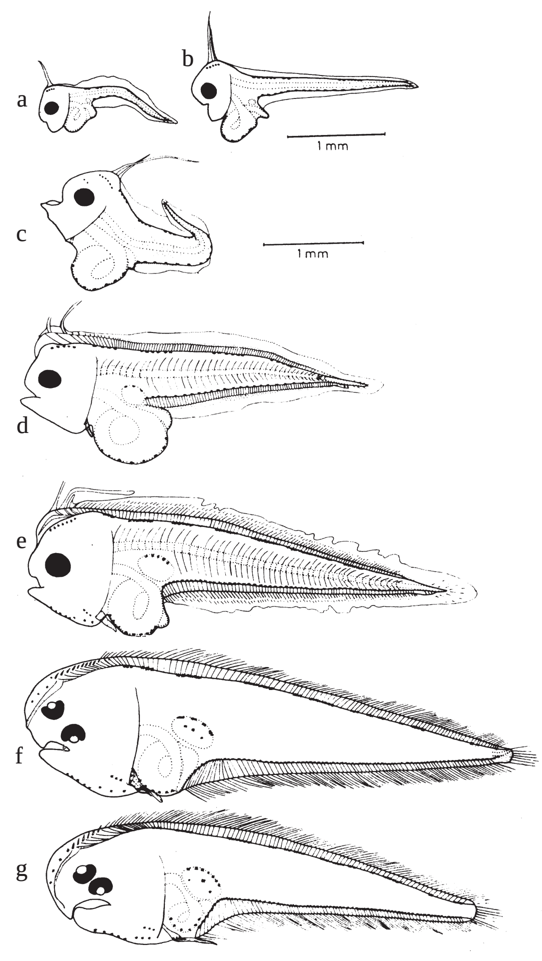



Fig. 58. Larvae of *Cynoglossus puncticeps* (a) 1.4 mm S.L. (b) 2.2 mm S.L. (c) 2.5 mm S.L. (d) 3.4 mm S.L. (e) 4.2 mm S.L. (f) Metamorphosed larva of *C. puncticeps* 4.9 mm S.L. (Balakrishnan & Devi, 1974)

At 1.4 mm (Fig. 58.a) dorsal fin fold commence at the level of the eye where a tentacular process and ray is present. At 2.2 mm (Fig.58.b) second elongated ray differentiated. Interspines differentiate at 2.5 mm (Fig.58.c). At 3.5 mm, bases of 98 dorsal and 79 anal rays discernible; anterior end of dorsal fin fold continues to grow beyond the elongated rays. Swim bladder occupies the space between 5th and 10th vertebrae.

In the metamorphosed larva of 4.9 mm (Fig.58.f) right eye lies in front of the left one. Tubular nostril in front of the left eye. Cleft of the mouth asymmetrical, the left oblique and the right curved, anus on the right side. 49 vertebrae. Dorsal fin fold extended to the snout and first interneural spine extends to its tip corresponding to the rostral hook of the adult. 107 dorsal and 83 anal rays, elongated dorsal rays lost, caudal with 7 rays, pectoral fin absent, 4 rays in the ventral fin.

***Cynoglossus brevis*** Gunther 1862

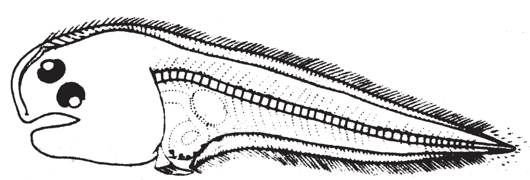


Fig. 59. Metamorphosed larva of C. brevis 4.0 mm standard length (Balakrishnan & Devi, 1974)

Metamorphose earlier than *C.puncticeps*. In the 4.0 mm metamorphosed larva, the right eye lies a little in front of the left one, cleft of the mouth assymetrical. Head length more, but the number of vertebrae (43), fewer than in *C.puncticeps*. Development of fin rays early, 94 dorsal and 76 anal rays discernible. Elongated rays of dorsal fin absent; pectoral fin absent, ventral fin has 4 rays.

***Cynoglossus cynoglossus*** Hamilton Buchanan, 1822

Robust body, myotome 47 at 1.6 mm (Fig.49.a) functional mouth and eye not differentiated indicating a longer larva than *C.puncticeps*. Mouth absent, intestine parallel to the body. Rudiments of first elongated dorsal rays supported by first interneural spines seen as a small tentacular organ at the anterior end of the dorsal fin fold. Irregular dark brown pigment patches and spots over the body.

At 1.9 mm (Fig.49.b), mouth developed, intensine seen as a circular coil, tentacular organ lengthier. 47 vertebrae countable in 3.5 mm larva (Fig.49.c), two elongated rays present in place of dorsal tentacle, rostral hook extends over to snout. Swim bladder present between 5th and 10th vertebrae. 97 dorsal, 78 anal and 7 caudal rays in 4.1 mm larva. In the metamorphosed larvae of 4.7 mm (fig.49.f) right eye lies a little in front of the left eye.

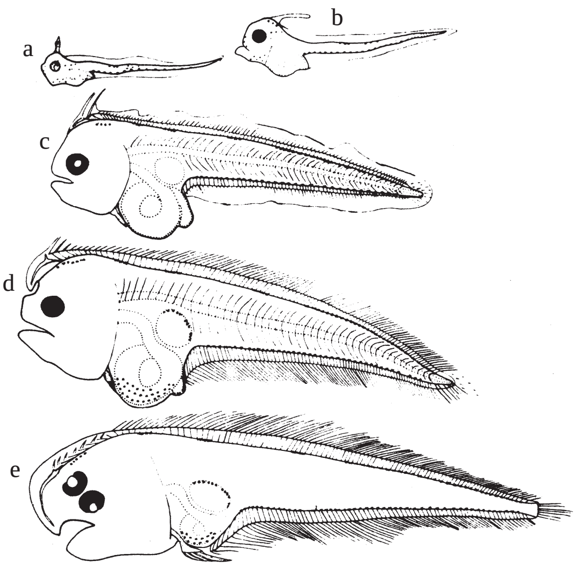



Fig. 60. Larva of *C. cynoglossus* (a) 1.6 mm SL (b) 1.9 mm SL (c) 3.5 mm SL (d) Metamorphosed larva of 4.7 mm (Balakrishnan & Devi, 1974)

102 dorsal, 76 anal and 7 caudal rays present. Elongated dorsal rays absent at the anterior end.

***Cynoglossus lida*** (Bleeker) 1852

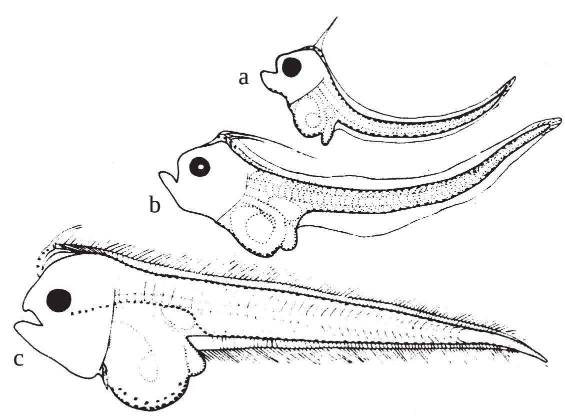



Fig. 61. Larva of *C. lida* : (a) 2.1 mm SL (b) 3.3 mm SL (c) 4.6 mm SL (Balakrishnan & Devi, 1974)

Ratio between standard length and depth at cleithra comparatively more than *C.puncticeps, C.brevis* and *C.cynoglossus*. At 2.1 mm, mouth and anus well developed, intestine a circular coil with rectal portion remaining separate from the rest; a small swim bladder present; two elongated rays at the anterior end of dorsal fin fold. At 3.3 mm, vertebral segments discernible, ventral fin rudiments visible. Remain a symmetrical post larva even at 4.6 mm (Fig.61. c). 45 vertebral segments, 100 dorsal and 82 anal rays discernible; interspines developed smaller than other species. Rostral hook reaches only half way over the snout.

***Cynoglossus macrostomus*** Norman

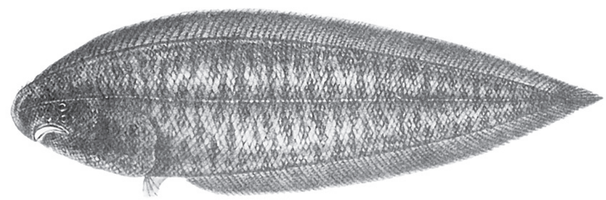


Fig. 62. *Cynoglossus macrostomus* (Day, 1971)

Common name Malabar sole

D 100-106; A 78-84; V 4; C 10

Body tongue-shaped.

Snout obtusely pointed; angle of mouth reaching well beyond lower eye, eyes nearly contiguous.

Two lateral lines on ocular side, separated by 14 to 16 rows of scales; no lateral line on blind side.

Scales ctenoid on both sides of body.

Colour: in life, ocular side light brown with dark brown mottling forming diffuse, irregular cross bands; blindside whitish, dorsal and anal fins grey-black.

Distribution: Inhabits shallow and sandy bottoms of the continental shelf, also in estuaries.

Order **TETRADONTIFORMES**

Gill opening restricted to lateral slits. opercular bones and branchiostigal rays covered by thick skin, pelvic fins absent or strongly reduced; anal fin spines absent; caudal fin rays 7 to 10; mouth small with strong teeth frequently coalesced into a biting plate.

Family **TETRADONTIDAE**

Body broadly rounded in cross-section, heavy and blunt. Head large, broad and blunt. Jaws with fused teeth.

Dorsal and anal fins inserted far posteriorly; no fin spines; pelvic fins absent.

Genus ***Chelonodon*** Muller

Nasal organ in form of a depression with slightly raised margin expanded before and behind into a pair of flaps, side naked.

***Chelonodon patoca*** (Hamilton -Buchanan)

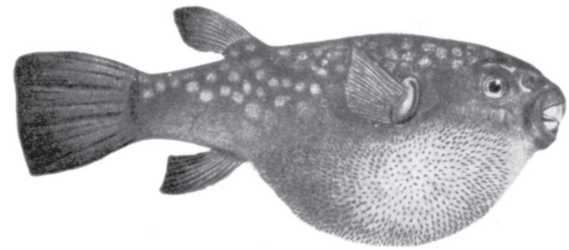


Fig. 63. *Chelonodon patoca* (Day, 1971)

Common name Gangetic puffer fish

D 9-10; A 8-10; P 15-16

Head very broad, upper profile of snout to caudal fin evenly arched; inter-orbital space flat and broad.

Nostril a round depression surrounded by a low rim produced into a posterior and anterior flap.

Body with a spiny patch on back, throat and belly; sides naked.

Colour: Body brown, belly golden yellow (in life); black and sides with white spots; juveniles have broad dark bars across back, between eyes, above base of pectorals and below dorsal.

Distribution: Indo-west pacific.

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# Fishery in Mangroves - A livelihood for Artisanal Fisherfolk

Fish/Prawn seed collection for aquaculture and marketing-adverse effect on capture fishery resources.

Traditional trap fishing - deleterious to natural recruitment to fish stock.

Pearl spot (*Etroplus suratensis*)- A prominent brackishwater species exploited from Kerala mangroves.

Eel (*Anguilla anguilla*)- Catadromous migrate from river to sea through an estuary/mangrove for breeding.

Cat fish (*Tachysuruas*)- from mangroves by gillnets and hook & line.

Processing & Marketing of mixed catch of fish, prawn & shellfish by artisanal fishery.

# Macrobenthos - Methods for Study

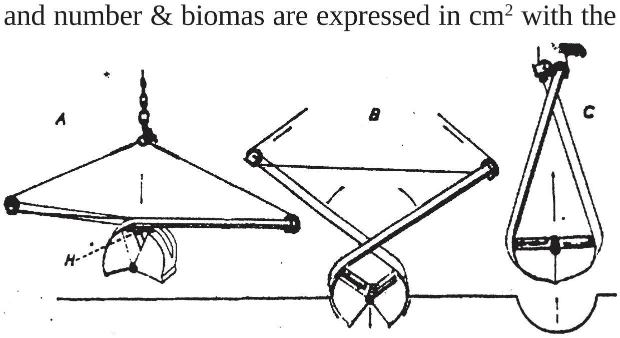
**K. Vijayakumaran**

The bottom fauna or benthos forms an important link in the food web of the aquatic ecosystems. Bottom dwelling fishes and crustaceans feed mainly on the benthic organisms and hence the abundance of benthic fauna is a major factor deciding the fishery potential of watery body. In recent years, long-term works on benthic communities has been gaining importance in pollution studies and assessment of ecosystem health. Therefore, study of the qualitative and quantitative aspects of benthos is very important in mangrove ecosystem biodviersity determination.

The macrofauna and meiofauna are mainly distinguished by their relative size and groups involved. It is generally accepted that those animals retained in 0.5 – 2.0 mm mesh depending on the nature of the substratum sieve are macrofauna and those which pass through these sieves but are retained by a sieve of about 60 µm mesh are termed meiofauna.

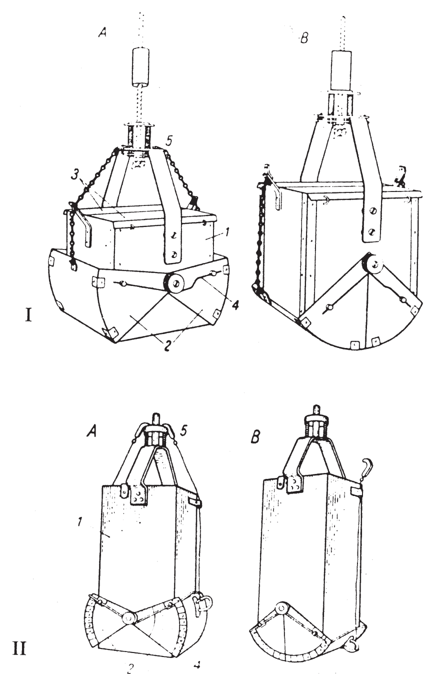
**Sampling**

A Peterson grab or van Veen grab (Fig.1) or Eckman grab can be conveniently used for collecting benthos samples. Surface area of grab is recorded and number & biomas are expressed in $cm^2$ with the

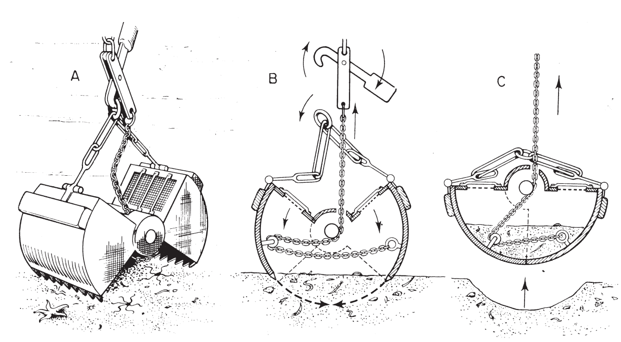



*van Veen grap in different stages of operation*

required conversion / multiplicatin for expressing number and biomass. While taking the grab sample quantity of the sediment must be checked because improper performance of grab may result in reduced quantity of sediment and thus erroneous values of population and biomass. In case of improper functioning of the grab, the sampling operation must be repeated. Record the sediment temperature immediately after the grab is taken out. Remove a sub-sample if sediment characteristics are to be analyzed.




*Ekman - Birge grab.* I. Initial form; II. Tall form as used by Borutzky. A, Open; B, closed. It is advantageous to use flexible cable rather than chains to hold the jaws open and to have the guides open rather than to ave the cable pass through a hole. 1, box; 2, jaws; 3, top lids; 4, spring which operates jaws; 5, jaw chain fastened on trip mechanism.




Petersen grab taking a sample on the sea bed (Redrawn from Hardy, 1959, and reproduced with permission from *Advances in Marine Biology, Vol.* 2)

## Processing of sample

Transfer the sediment without spilling into a tub or bucket. Wash the sediment through a sieve with copious flow of water, taking care not to spill over or clog the mesh. A series of sieves can be used if the size composition of the fauna has to be determind. Three sieves of different mesh sizes 2000 µm (BSS-8), 1000 µm (BSS-16) and 500 µm (BSS-30) in that order would give reasonably good information about the size structure of the fauna (Vijayakumaran, 2003). The different specification (numbers) of test sieves and the corresponding mesh sizes are given in *Appendix -3*. If information on size is not important a single sieve of 500 µm can be used for segregating the macrofauna.

The benthic organisms retained in each sieve have to be collected in separate bottles and preserved with 4 percent formalin onboard (collect the sample in approximately 100 ml water and add 10 ml of 40% formalin). A few drops of Rose Bengal stain (1:500) added to this sample would facilitate sorting as the organisms would take deep purple colour. Use of a soft brush for transferring animals is quite desirable.

## Processing in the Laboratory

Larger animals can be picked up, enumerated and weighed separately before segregation and enumeration of smaller animals is done. Smaller animals can be sorted and enumerated under a dissection microscope using fine brushes, needle and forceps. Care must be taken not to exert pressure on any delicate worms to cause breakage and counting of the two pieces as separate animals. The displacement volume and wet weight (after properly blotting the moisture with filter paper) of animals sorted out can be taken before identification and enumeration. The organisms may be kept on filter paper and adhering moisture can be removed without damaging the animal and wet weight may be taken by a precession balance. After taking the weight the qualitative composition of sample is assertained.

Before estimation of dry weight, shells and other hard materials should be removed. The organisms can be dried at 80 $^{o}$C to constant weight. (if neccessary it can also be dried at 105 $^{0}$C and weigh without much delay, but fat content may be melted out which may affect the exact weight). Being a destructive process, it is not always practicable to estimate the dry weight of all samples. A convenient method will be to workout a formula for conversion of wet weight (or volume) into dry weight. This can be achieved by taking dry weight of a few numbers of samples of which wet weight (volume) are known and working out a conversion factor based on the relationship.

The sorted animals can be preserved in alcohol in glass specimen tubes (some plastic tubes such as Tarson's tubes may crack or leak and cause drying up of specimens). Formalin should never be used for preserving or fixing Sponges and Ctenophores, since rapid maceration or total destruction of the animal may occur. Though formalin is a better fixative than alcohol in microscopy, other reagents such as Formaldehyde Alcohol Aceticacid (FAA) or Bouin's reagent are preferable. A more convenient preservative is the alcohol-glycerin, in which glycerin will prevent total desiccation as well as act as a clearing agent (see *Appendix-2* for methods of preparation)

A systematic order has to be followed in recording the number of animals under different taxa. A tentative listing is provided in *Appendix-1*. Organisms difficult to identify must be kept in separate specimen tubes properly labeled for future identification. After proper identification, the same can be incorporated in the data sheet of the relevant sample. The different ecological indices can be worked out as per the formulae given in *Appendix-4.*

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## Appendix – 1

### SUGGESTED CLASSIFICATION OF FAUNA

A typical systematic order of benthic and planktonic organisms is presented below as per UNESCO (1983) and Gosner (1971). The changes that may come into effect in the classification can be incorporated without affecting the general pattern.

PROTOZOA
- Foraminifera
- Radiolaria

PORIFERA
- Calcarea
- Hexactinellida
- Demospongia

CNIDARIA
- Hydrozoa
- Scyphozoa
- Anthozoa

CTENOPHORA

PLATYHELMINTHES
- Turbellaria
- Trematoda
- Cestoda

RHYNCHOCOELA

ASCHELMINTHES
- Rotifera
- Gastrotricha
- Kinorhyncha
- Paripulida
- Nematoda
- Nematomorpha

ENTOPROCTA

ECTOPROCTA

TARDIGRADA

CHAETOGNATHA

BRYOZOA

PHORONIDA

BRACHIOPODA

MOLLUSCA
- Polyplacophora
- Aplacophora
- Gastropoda
- Scaphopoda
- Bivalvia
- Cephalopoda

ANNELIDA
- Polychaeta
- Myzostomaria
- Oligochaeta
- Hirudinea

SIPUNCULIDA
ECHIURIDA
ARTHROPODA

- MEROSTOMATA
- ARACHNIDA
- PANTOPODA
- CRUSTACEA
  - Cephalocarida
  - Branchiopoda
  - Ostracoda
  - Copepoda
  - Mystacocarida
  - Branchiura
  - Cirripedea
  - Malacostraca
- INSECTA

PYCNOGONIDA
POGONOPHORA
ECHINODERMATA

- CRINOIDEA
- HOLOTHUROIDEA
- ECHINOIDEA
- ASTEROIDEA
- OPHIUROIDEA

HEMICHORDATA
TUNICATA
CEPHALOCHORDATA
CYCLOSTOMATA
SELACHII
TELEOSTEI

## Appendix- 2

| **Lugol's Iodine** |
|---|
| Dissolve 100 g KI in 1 litre of distilled water then dissolve 50-g iodine (crystalline) and add 100 ml of glacial acetic acid. Decant the solution to remove precipitates. |
| **Bouin's Reagent** |
| Mix 75 parts picric acid (saturated solution made by dissolving 1 g of picric acid crystals to about 75 ml distilled water), 25 parts formalin and 5 parts glacial acetic acid. |
| **FAA** |
| Mix 10 parts formalin, 50 parts 95 % alcohol, 2 parts glacial acetic acid 40 parts water. |
| **Alcohol-Glycerin** |
| Mix 19 parts 70% alcohol (ethyl or isopropyl) and 1 part glycerin. |

## Appendix - 3

## SPECIFICATIONS OF TEST SIEVES

| ***B.S.S*(410/1969)** | **A.S.T.M.*(11-70)*** | **I.S.I*(460/1972)*** | **Mesh size*(μ m)*** |
|---|---|---|---|
| 4 | 5 | 4.00 mm | 4000 |
| 5 | 6 | 3.35 mm | 3353 |
| 6 | 7 | 2.80 mm | 2812 |
| 7 | 8 | 2.36 mm | 2411 |
| 8 | 10 | 2.00 mm | 2057 |
| 10 | 12 | 1.70 mm | 1680 |
| 12 | 14 | 1.40 mm | 1405 |
| 14 | 16 | 1.18 mm | 1204 |
| 16 | 18 | 1.00 mm | 1003 |
| 18 | 20 | 850 μ m | 850 |
| 22 | 25 | 710 μ m | 710 |
| 25 | 30 | 600 μ m | 600 |
| 30 | 35 | 500 μ m | 500 |
| 36 | 40 | 425 μ m | 420 |
| 44 | 45 | 355 μ m | 355 |
| 52 | 50 | 300 μ m | 300 |
| 60 | 60 | 250 μ m | 250 |
| 72 | 70 | 212 μ m | 210 |
| 85 | 80 | 180 μ m | 180 |
| 100 | 100 | 150 μ m | 150 |
| 120 | 120 | 125 μ m | 120 |
| 150 | 140 | 106 μ m | 105 |
| 170 | 170 | 90 μ m | 90 |
| 200 | 200 | 75 μ m | 75 |
| 240 | 230 | 63 μ m | 63 |
| 300 | 270 | 53 μ m | 53 |
| 350 | 325 | 45 μ m | 45 |
| 400 | 400 | 37 μ m | 37 |
| 500 | - | 25 μ m | 25 |

** B.S.S. = British Standard Sieves; ASTM = Americant Standards Test Mesh; ISI = Indian Standards Institution*

## Appendix – 4

# ECOLOGICAL INDICES

### *INDICES OF DISPERSION*

A number of indices based on variance to mean ratio (as the variance and mean are equal in theoretical Poisson distribution) has been suggested to test i) the *equality* of the variance-to-mean in a Poisson series and ii) measure the degree of clumping of a population of organisms. The details of formula of three such ratios being widely used are given below.

**Index of Dispersion (ID)**

This, being the variance to mean ratio, is the simplest of all indices of dispersion and is calculated as:

$$ID = \frac{s^2}{\bar{x}}$$

where $\bar{x}$ and $s^2$ *are* sample mean and variance respectively.

**Index of Clumping (IC)**

A modification of Index of Dispersion suggested by David and Moore (1954) is termed as Index of Clumping (IC) given by the formula:

$$IC = (s^2 / \bar{x}) - 1 = ID - 1$$

where $\bar{x}$ and $s^2$ *are* sample mean and variance respectively.

**Green's Index (GI)**

When population is clumped, ID is strongly influenced by 'n' the number of individuals in the sample. Green (1966) suggested a modification to Index of Clumping, which is independent of 'n' and is known as Green's Index (GI)

$$GI = \frac{(s^2/\bar{x}) - 1}{n-1} = \frac{IC}{n-1}$$

The properties of the three indices of dispersion at maximum regularity, randomness and maximum clumping are summarized in the following table:

**Morisita's Index ($I_d$)**

Morisita (1971) proposed an index, (almost similar to the Lloyd's Index of Patchiness), that is unaffected by changes in density due to random thinning. Moristia's index is calculated as:

$$I_d = \left(\frac{n}{n-1}\right)\left(\frac{\overset{*}{x}}{\bar{x}}\right)$$

Where, $n$ is the total number of individuals in the sample and $\overset{*}{x}$ is the mean crowding given by the formula:

$$\overset{*}{x} = \bar{x} + IC$$

### DIVERSITY INDICES

The concept of species diversity in community ecology has been intensely debated by the ecologists over the years. Species diversity may be thought of as being composed of two components. The first is the number of species in the community, which ecologists often refer to as species **richness**. The second component is the species **evenness** or **equitability**.

There are literally an infinite number of diversity indices. Two of the commonly used indices, which are also needed for Hill's Diversity numbers, are Simpson's index and Shannon's Index.

***Simpson's Index ($\lambda$)***:

Simpson (1949) proposed the first diversity index used in ecology as:

$$\lambda = \sum_{i=1}^{s} p_i^2$$

Where $p_i$ is the proportional abundance of the ith species, given by

$$p_i = \frac{n_i}{N}, \text{ i } = \text{, i} = 1,2,3, \ldots\ldots, S$$

| INDEX | VALUE OF INDEX AT | | |
|---|---|---|---|
| | **Maximum Uniformity** | **Complete Randomness** | **Maximum Clumping** |
| **Index of Dispersion(ID)** | 0 | 1 | n |
| **Index of Clumping (IC)** | - 1 | 0 | n – 1 |
| **Green's Index (GI)** | - 1/ (n-1) | 0 | 1 |

and $n_i$ is the number of individuals of the $i^{th}$ species and N is the known total number of individuals for all *S* species in the population.

***Shannon's Index H'***

Shannon index *H'* has been probably the most widely used index in community ecology. Two of the salient features of this index are that *H'* assumes value 0 if only one species is observed in the sample and *H'* assumes maximum value when all S species are represented by the same number of individuals.

$$H' = \sum_{i=1}^{S} \left(\frac{n_i}{n}\right) \ln\left(\frac{n_i}{n}\right)$$

Where, $n_i$ is the number of individuals belonging to the $i^{th}$ of S species in the sample and *n* is the total number of individuals in the sample

The series of diversity numbers presented by Hill (1973) are probably the easiest to interpret ecologically.

***Hill's Diversity Number 0***:

$$N0 = S$$

Where *S* is the total number of species. N0 is obviously the number of all species in the sample regardless of their abundance.

***Hill's Diversity Number 1***:

$$N1 = e^{H'}$$

Where *H'* is Shannon's index defined above. N1 gives the number of abundant species in the sample.

***Hill's Diversity Number 2***:

$$N2 = 1/\lambda$$

Where λ is Simpson's index defined above. N2 gives the number of very abundant species in the sample.

**Richness Indices**

A straight forward index of species richness would be *S*, the total number of species in a community. However since S depends on the sample size, its utility as a comparative index is limited. Therefore a number of indices have been suggested based on the relation between S and n, the total number of individuals observed, which increases with increasing sample size. The two well-known richness indices are given below:

***Margalef (1958) Index***

$$R1 = \frac{S-1}{\ln(n)}$$

Where *S* is the total number of species in the community and *n* is the total number of individuals observed.

***Menhinick (1964) Index***

$$R2 = \frac{S}{\sqrt{n}}$$

Where *S* is the total number of species in the community and *n* is the total number of individuals observed.

**Evenness Indices**

In an attempt to quantify the evenness component of diversity, a number of indices have been proposed. Five of the commonly used evenness indices are described below:

(H,S, N0, N1, N2 and λ are as difined earlier)

***Evenness Index 1 (E1)***.

This is the familiar J' of Pielou (1975,1977) and is probably the most common evenness index used by ecologists

$$E1 = \frac{H'}{\ln S} = \frac{\ln(N1)}{\ln(N0)}$$

***Evenness Index 2 (E2)***.

Sheldon (1969) proposed an exponentiated form of E1 as an evenness index, which is calculated as:

$$E2 = \frac{e^{H'}}{S} = \frac{N1}{N0}$$

***Evenness Index 3 (E3)***.

Heip (1974) proposed an index from which the minimum of the diversity index is subtracted and is expressed as:

$$E3 = \frac{e^{H'}-1}{S-1} = \frac{N1-1}{N0-1}$$

***Evenness Index 4 (E4)***.

Hill (1973 a&b) proposed the ratio of N2 to N1 (ratio of number of very abundant species to abundant species) as evenness index, which will tend to become one as a single species tend to dominate.

$$E4 = \frac{1/\lambda}{e^{H'}} = \frac{N2}{N1}$$

***Evenness Index 5 (E5)***.

This index, similar in form to E3 and known as the modified Hill's ratio, approaches zero as a single species becomes more and more dominant in a community. This is a desirable property for an evenness index:

$$E5 = \frac{1/\lambda - 1}{e^{H'}-1} = \frac{N2-1}{N1-1}$$

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# Benthos - Polychaetes

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## Introduction

Polychaetes are one of the major benthic group of animals just like molluscs and crustaceans. Globally 12,620 species of Polychaetes are supposed to be occurring and in India around, 1,093 species representing 8.66% of the total number of polychaete species are known. Polychaetes are very important in the marine and brackish water ecosystems extending from the abyssal depths to the inter-tidal regions. Its major role is through the biomass formation in the benthic as well as in the pelagic aquatic systems as sedentary and pelagic polychaetes and through the different larval forms released by them. It also forms the major food for crustaceans, molluscs as well as for fishes. Because of the special adaptive nature of this group, Polychaetes are distributed in almost all ecological conditions, both in the macro and micro environments having different ranges of salinities and dissolved oxygen. Certain species survive in the anaerobic conditions also.

In the open sea as well as in the brackish water environments of the mangroves also species are widely distributed and almost all families of the benthic polychaetes occur in the mangroves depending upon the substratum, salinity, dissolved oxygen and the tidal influence.

## Polychaetes of the mangrove eco-systems.

Polychaete species belonging to the families of Aphroditidae, Amphinomidae, Hesionidae, Phyllodocidae, Syllidae, Nereidae, Eunicidae, Onuphidae, Glyceridae, Spionidae Cirratulidae, Capitellidae, Sabellariidae, Amphectenidae, Terebellidae, Chaetopteridae, Sabellidae and Serpulidae are commonly occurring in the mangrove ecosystems. Among these, members of the families of Nereidae, Onuphidae, Eunicidae, Sabellariidae, Spionidae and Serpulidae aggregate colonies and develop parallel community systems in different localities. The species composition is repeated from one mangrove to another irrespective of the distance and depending upon the uniformity and parallelism of the environment.

## Earlier studies on polychaete taxonomy

The study of polychaetes in India dates back to the early 1920 (Southern 1921, Gravely 1927). A comprehensive account on this group is given by Fauvel (1953) in which he has described 34 families and 450 species and is a classical reference on this subject even though he had described 300 species of polychaetes of the Indian Museum – Culcutta (Fauvel, 1932). Day's work on the South Afrcian polychaetes (1967) have given a detailed key for the identification of majority of families and species even though some of the later workers have increased the number of families and genera through revisions. In India Ganapathy & Radhakrishan (1958), Thampi & Rangrajan (1964) Cherian (1966), Achari (1969 & 1972) are some of the later authors dealt with this subject. Recently Hartman (1974) has presented a Bibliography of the polychaetes from India giving 59 families, 315 genera and 860 species as per the later revisions of this group.

The list of polychaete families presented by Hartman and the pictorial key for the identification given by Day are presented here for new researchers for identification up to the family level.

## List of Polychaete families reported from Indian region

| Errantia | Sedentaria |
|---|---|
| Aphroditidae | Orbinidae |
| Polynoidae | Paraonidae |
| Polyodontidae | Spionidae |
| Peisidicidae | Magelonidae |
| Sigalionidae | Disomidae |
| Pisionidae | Poecilochaetidae |

Chrysopetalidae
Amphinomidae
Euphrosinidae
Spintheridae
Phyllodocidae
Alciopidae
Lapadorrhynchidae
Lacydonidae
Tomopteridae
Hesionidae
Pilargidae
Syllidae
Nereidae
Nephthydae
Sphaerodoridae
Glyceridae
Goniadidae
Onuphidae
Eunicidae
Lumbrineridae
Arabellidae
Lysaretidae
Dorvilleidae
Heterospionidae
Chaetopteridae
Cirratulidae
Acrocirridae
Cossuridae
Flabelligeridae
Scalibregmidae
Sternaspidae
Capitellidae
Arenicolidae
Maldanidae
Oweniidae
Sabellariidae
Pectinariidae
Ambaretidae
Terebellidae
Trichobranchidae
Sabellidae
Serpulidae
Spirorbidae
Archiannelida

Biologically polychaetes are highly adapted compared with other groups. Because of the peculiar reproductive adaptability of polychaetes they are widely distributed and majority of them are cosmpolitain in distribution. Though sexes are separate and fertilization is external, some hermaphrodites, show protandric hermaphroditism also. The protracted larval phase of some of the species also help them for their wide distribution. The polychaete faunal diversity of the Indian region is very much comparable with the South African and North Australian region since there are close similarities of the faunal structure of these regions. In mangroves also such similarities can be observed as parallel community patterns.

**Polychaetes**

Several studies on polychaetes have been conducted in India by different workers like Willey (1908), Southern (1921), Fauvel (1932 & 1953) Misra et al (1984), Misra (1995) etc. Fauvel (1953) recorded 283 species of marine and estuarine polychaetes from different parts of India, of which only 47 species were esturine. Misra (1998) reported the occurance of 167 species of polychaetes belonging to 38 families from different brackish water bodies in India.

**Class Polychaeta**

**(Main Diagnostic characters):**

i. Annulated worms with numerous chitinous bristles on parapodia and lateral processes of the segment's body-wall.

ii. Various appendages like antennae, palps, cirri and gills are present.

iii. Exclusively marine animals, very exceptionally they are encountered in fresh water.

iv. Sexes separate

**Special Morphological Charaters**
**(General Scientific Terms)**

**Prostomium, Metastomium and Pygidium:**

The elongated body divided into numerous segments, consist of the anterior cephalic lobe or *Prostomium; a Metastomium* including all the following segments and a *Pygidium*, the last segment.

**Styles and statodes:**

These are epidermic solid projection (appendages) of polychaetes.

**Phore:**

When the antennae, palps and cirri are borne on a hollow base, is termed as *phore*. Such an antenna is then divided into a solid distal part or *ceratostyle* and a basilar hollow part or *ceratophore;* a palp is divided into a *palpostyle* and a *palpophore*, a cirrus into a *cirrostyle* and a *cirrophore.*

**Parapodia:**

Parapodia or feet are complicated lateral processes, provide the most important features for the identification of the species. Typically, each segment carries one pair of parapodia divided into two *rami*; a dorsal one, called *notopodium* and a ventral one, called *neuropodium.*

When both rami are borne on a common base the biramous foot is said to be *monostichous*; when both rami are quite distinct and more or less apart, it is termed as *distichous.* In biramous parapodium of *Nereis* there are:1) two setigerous lobes (or chaetigerous suckers) carrying the setae and supported by a stout, enclosed, bodkin-like bristle or *aciculum*. 2) parapodial lobes, lips or fillets 3) a dorsal and ventral *cirrus*.

*Biramous parapodia*: When both rami are nearly equally developed.

*Sub- biramous parapodia*- with a dorsal cirrus but the dorsal setal sack and setae more or less reduced.

*Sesquiramous parapodia* – when the dorsal lobe is reduced to a few bristles or acicula.

*Uniramous parapodia* – when the dorsal ramus is practically wanting, being reduced to the dorsal cirrus.

***Tori and uncini*** –in the Sedentaria, the neuropodia or ventral rami, are often reduced to mere transverse ridges, called *uncinigerous* tori, with out a cirrus and carrying short hooks, known as *uncini*.

***Pleae*** – when the setae are short, stout, bodkin shaped or flattened, paddle or oar-shaped, they are called paleae.

***Homogomph and Heterogomph*** – when both side of the articulation of the setae are the same length, it is termed as homogomph and when they are unequal, termed heterogomph.

**Sub–class-Errantia (Diagnostic characters).**

i. Long vermiform body with numerous uniform segments, except the first near to the mouth.

ii. Cephalic appendages like-antennae, palps and tentacular cirri are present; feet uniramous or biramous, with both rami hardly different; acicula present; gills are present frequently above the feet.

**Sub-class-Sedentaria (Diagnostic characters).**

i. Body divided into distinct regions.

ii. Head small, hardly distinct or greatly modified.

iii. Parapodia generally simple, the ventral rami are often with tori, pinnules, hooks or uncini; gills usually limited to a part of the body.

iv. Usually tubiform

**Key to the families of polychaetes under**

**Sub-class-Errantia.**

1. Pharyngeal armature complex ……. **Eunicidae.**

   Pharyngeal armature simple or absent …… 2

2. Tentacles not more than three…..3

   Tentacles more than three….4

3. Dorsal cirri short or of moderate length, not moniliform; pharynx armed with a single pair of strong toothed jaws; tentacles two; parapodia almost biramous……….**Nereidae.**

   Dorsal cirri long and more or less distinctly moniliform; pharynx cylindrical, armed with a small pair of jaws, usually only with stylets or unarmed; Tentacles two or three; Parapodia sesquiramous or biramous …………… **Hesionidae.**

4. Palps small; prostomium conical, slender, annulate, terminated by four small tentacles arranged in the form of a cross; pharynx large, covered with papillae armed with at least four teeth; parapodia biramous………………….. **Glyceridae.**

   Palps absent; prostomium more or less normal; parapodia with foliaceous cirri; without sickle shaped, gill generally uniramous; general appearance including the single pair of eyes normal; tentacles four or five …………………….. **Phyllodocidae**.

**Polychaeta – Sedentaria.**

1. Body clearly divided into regions……..4

   Body not clearly divided into regions…….2

2. Palps present, elongated, tentacle-like, two in number, not retractile into the mouth, without suckers; parapodial lamellae erect, dorsal branchiae cirriform; hooded hooked setae ……………….**Spionidae.**

   Without tentacle-like palp …………………… 3

3. Prostomium blunt, without appendages or with a crown of lacinated lobes; without branchiae; ventral tori with many rows of very small uncini; Sandy tube…………**Owenidae.**

   Prostomium with a keel, or a rimmed cephalic plate; An anal plate or an anal funnel with cirri; without branchiae; ventral tori with elongated sigmoid hooks………………..**Maldanidae.**

4. Terminal branchial tuft absent; without opercular setae; prostomium conical, without process; branchiae on many segments; with uncinigerous tori; anterior region abranchiate; posterior region with branchiae simple rudimentary or wanting. In the abdominal region dorsal and ventral tori with sigmoid hooded hooks ……………**Capitellidae.**

   Genus – *Talehsapia* Fauvel, 1932

   The characters of the genus are those of the only one species

1. *Talehsapia annandalei* Fauvel, 1932

   Body filiform, cylindrical; teguments smooth and shining; first five segments slightly swollen; the prostomium is a blunt cone; proboscis soft, cylindrical, transparent, without any papillae; pharynx extending to the middle of the 5th setigerous segment; the setae are all simple, straight or slightly curved; two short anal cirri.

Genus – *Eteone* Savingny, 1818

Body linear, with numerous segments; prostomium triangular, with four small tentacles; generally two small eyes; two pairs of tentacular cirri; dorsal cirrus absent on the second setigerous segment; proboscis smooth, or with soft papillae and small chitinous tubercles; dorsal and ventral cirri foliaceous; setae compound.

2. *Eteone barantollae* Fauvel, 1932.

Body filiform, sub-cylindrical, with segments; prostomium broader than long and notched on each side; two very small black eyes; four small, short, knob-like tentacles; proboscis smooth and transparent at the base, and with five longitudinal rows of large, soft, depressed, rounded or squarish papillae anteriorly; two pairs of tentacular cirri subulate, somewhat lanceolate and flattened; ventral cirri conical or oval, setae are short.

3. *Eteone* (mysta) *ornata* Grube, 1877.

Body elongated, with three striking longitudinal rows of violet pigmented spots upon a pale-yellowish colour; towards the middle part of the body the pigmented spots become gradually smaller and blend into a single streak, while in the posterior region of the body they entirely disapper; dorsal cirri comparatively small and borne on a distinct stalk; prostomium; two eyes, small and dot-like.

Genus – *Neanthes* Kinberg, 1866

Vermiform body with numerous segments; two tentacles; two ovoid palps; four eyes; four pairs of tentacular cirri; proboscis with two horny, curved jaws and conical horny paragnaths; parapodia usually biramous with an exception for the first two setigerous segments, which are uniramous; dorsal and ventral cirri present; spinigerous and falcigerous compound setae.

*4. Neanthes chingrighattensis* (Fauvel, 1932)

About 5-10 cm in length; prostomium without any frontal groove; pharynx eversible with paragnaths on both rings; biramous parapodia with 3 notopodial ligules; neuropodium with 3 lobes; spinigers setae; chitinous paragnaths are present in oral ring but absent in basal ring; posterior feet elongated and lamellate with dorsal cirri.

Genus – *Perinereis* Kinberg, 1866

Parapodia biramous; horny paragnaths on both rings of the proboscis; paragnaths, transverse, ridge-shaped, or a transverse row of more or less flattened denticles.

5. *Perinereis cultrifera* Grube, 1878

Prostomium sub-pyriform with dark longitudinal bands of pigments between anterior pair of eyes; pharynx eversible with paragnaths on both rings; parapodia biramous; notopodia with 2 blunt finger like subequal ligules and a small anterior acicular lobe; neuropodia with a bluntly conical setigerous lobe and a blunt inferior ligule.

*6. P. nigropunctata* Horst, 1889

Pharynx eversible with paragnaths on both rings; notopodia with 2 ligules and a small anterior acicular lobe, superior notopodial ligules enlarged bearing dorsal cirri on upper distal margin; neuropodia with a bluntly conical setigerous process and a blunt club shaped inferior ligule.

Genus – *Dendronereides* Southern, 1921

Pharynx eversible with soft papillae on both rings; tentacular cirri 4 pairs; parapodia biramous; branchiae present as subdivisions of notopodial superior lobes; neuropodia inferior; ligule absent.

7. *Dendronereides gangetica* Misra, 1995

Prostomium deeply indented with 2 short tapered antennae; tentacular cirri 4 pairs; pharynx eversible with soft papillae on both rings; biramous parapodia with 3 conical notopodial ligules and a short anterior acicular lobe; neuropodium with bluntly bifid presetal lobe and short rounded postsetal lobe; branchial filaments arranged in whorl.

8. *D. heteropoda* Southern, 1921

Prostomium broad, slightly indented in front, with 2 small antennae; tentacular cirri 4 pairs, longest pair reaching setiger 4-6; pharynx eversible with soft papillae on both rings; biramous parapodia with 2-3 notopodial ligules; neuropodium with 2 anterior and a posterior digitiform lobes; branchiae arising below dorsal cirrus, in the form of branched bunches of filaments, starting from setiger 7-8 and extending up to setiger 20-22.

Genus- *Dendronereis* Peters, 1854.

Proboscis with only soft papillae; prostomium deeply indented in front; dorsal cirrus of a number of anterior segments bearing numerous branchial filaments; setae all homogomph spinigerous.

*9. Dendronereis aesturaina* Southern, 1921

Anterior 10-12 segments light green with brown pigments, while posterior segments are light coloured; prostomium; deeply cleft anterodorsally; pharynx eversible with a pair of jaws; maxillary ring smooth and oral ring with soft papillae; parapodia biramous from third setiger with 3 notopodial ligules, 10-12 neuropodial lobes and inferior ligule; number of ligules and lobes gradually decreasing posteriorly; branchiae as bipinnate divisions of dorsal cirri commencing from setiger 15 and extending up to 21-22; setae all homogomph spinigerous with slender, minutely serrated blades.

Genus – *Namalycastis* Hartman, 1959.

Notopodia without branchiae; parapodia sub-biramous throughout, without ligules.

*10. Namalycastis indica* (Southern, 1921.)

Prostomium wider than long, with a short anteromedian groove; antennae short and slender; tentacular cirri long and slender; parapodia sub-biramous; notosetae 1 or 2 per setiger; dorsal cirri gradually increasing in size, broad and flattened in middle and posterior setigers.

*11. Namalycastis fauveli* Rao, 1981

Prostomium wider than long, without anteromedian groove; antennae very small and indistinct; tentacular cirri short. parapodia sub-biramous, with reduced notopodia; neuropodial falcigers usually heterogomph.

Genus – *Glycera* Savigny, 1818.

Body rounded, tapering at both extremities; segments two or three-ringed. prostomium acutely conical, ringed, with four small terminal tentacles; proboscis club-like, with four hooked horny jaws; parapodia biramous, with a stumpy dorsal cirrus; branchiae present or absent, simple or branched, permanent or retractile into the foot; ventral setae compound, spinigerous; dorsal setae simple.

*12. Glycera tesselata* Grube, 1863.

Branchiae absent. parapodia with two anterior equal elongated lobes and two posterior lobes much shorter, rounded and equal to each other; papillae of the proboscis long and slender; support of the jaws with two long dagger-like processes.

13. *Glycera alba* Rathke, 1843.

Branchiae simple; parapodia with two anterior, subequal, triangular or cirriform lobes and two posterior lobes; papillae of the proboscis obliquely truncated with a transparent nail-like appendage; supports of the jaws triangular, with a single process.

Genus – *Diopatra* Audouin and Milne-Edwards.

Head rounded; two pad-like palps; two small oval frontal tentacles; five long occipital tentacles; an achaetous segment bearing two small tentacular cirri; dorsal cirri subulate while ventral cirri subulate in a few anterior parapodia; pseudo-compound bristles in the anterior parapodia, succeeded by simple setae, comb-setae and acicular setae; gills large; lower jaw with two pieces; upper jaw with a pair of mandibles, three pairs of toothed plated and an unpaired one; tube membranous, sticking in the sand or mud.

*14. Diopatra cuprea cuprea* Bose 1802.

Prostomium with a pair of oval cushion-like palps, and 5 occipital antennae; tentacular cirri slender; anterior parapodia well developed, supported by 2-3 acicula, each with a long, conical postsetal lobe and a short, rounded presetal lobe; first 4 or 5 setigers with presetal lobes having larger superior and smaller inferior processes.

Genus – *Lumbriconereis* Blaninville, 1828

Body long and cylindrical; prostomium conical or globular, devoid of palps and tentacles; eye absent; dorsal cirri absent or reduced to a small knob; ventral cirri absent; gills absent; parapodia with two unequal ligules; simple winged setae and simple or compound hooks; lower jaw (labrum); upper jaw with a pair of mandibles and three pairs of toothed plates.

15. *Lumbriconereis heteropoda* Marenzeller, 1879.

Prostomium conical; parapodia increase in length posteriorly, with posterior cirriform ligule long and often erect; only simple capillary setae in the anterior feet followed by winged capillaries and unjointed hooks with small denticles above the main fang.

16. *L. Polydesma* Southern, 1921

Very slender elongated body; prostomium rounded; feet uniform in the middle and posterior parts, with an anterior short rounded lobe and a posterior longer, conical or cirriform one; only capillary winged setae in the 28 anterior parapodia, which do not disappear in the middle and posterior parapodia; the hooks, from the 29$^{th}$ parapodium are all unjointed, with 6-10 small denticles above the main fang; acicula colourless.

Genus – *Polydora* Bose

Prostomium blunt or notched in front, ending posteriorly in a crest, gills begin beyond the 6$^{th}$, 9$^{th}$ parapodium, rarely on the 2$^{nd}$ , fifth setigerous segment highly modified, with peculiar stout dorsal bristles; simple or lobed anal cup.

17. *Polydora normalis* Day 1963

Prostomium deeply notched anteriorly; eyes absent; branchia commencing from setiger 7-9 as slender filaments, continuing nearly to the posterior end; parapodia of first setiger each with reduced notopodium in the form of a papilla and a well developed neuropodial lamella; parapodia of succeeding setigers each with notopodium protecting as a broad acicular lobe; neuropodium having superior and inferior presetal lamellae and a median rounded postsetal lobe.

Genus – *Mastobranchus* Eisig.

Thorax of eleven setigerous segments with only dorsal and ventral capillary setae; abdomen with capillary setae and hooks on the dorsal ramus and hooks only on the ventral ramus; thoracic feet claviform; anterior abdominal segments long, cylindrical, the posterior ones strobileform or campanulate. parapodial gills simple, next compound and retractile.

18. *Mastobranchus indicus* Southern, 1921

Prostomium small, rounded; no eyes; skin of the anterior region tessellated; 4 pairs of genital pores behind the segments 8-11; tori in segments 2-4 very short, loger on the subsequent segments; the right ventral bundles of the 11$^{th}$ parapodium contain two very elongate hooks; the dorsal bundles on 13$^{th}$ and 14$^{th}$ segments contain only capillary setae, the ventral bundles contain hooks that are much larger and shorter than those of the right 11$^{th}$ foot; In the dorsal bundle of the 15$^{th}$ segment there are only hooks.

Genus – *Capitella* Blainville.

Thorax with 9 segments; anterior setigerous segment absent; either first 4 segment with capillary setae only, then next 3 segments with mixed hook and capillary setae in both rami and then genital spines in segments 8-9; branchiae absent.

19. *Capitella capitata* Fabricius, 1780

Body very small, generally varies from 30 to 40 mm in length; prostomium conical with a pair of ventral eyes; thorax of 9 segments, with capillaries in both rami from segments 1-6; segment 7 variable, with capillaries only or hooks only or both; in females, segments 8-9 with hooks in both rami, bust in males, genital hooks replace notosetae; abdominal segments with long-shafted hooks in both rami.

Genus – *Parheteromastus* Manro.

Thorax with 12 segments; capillary setae only in first 4 thoracic setigers; hooks only in succeeding setigers; branchiae absent.

*20. Parheteromastus tenuis* Manro, 1937.

Worms thread like; prostomium bluntly conical; thorax with 12 segments, first segment achaetous; setigers 1-4 with short capillaries in both rami; setigers 5-11 with long-handled hooked hooks in both rami; abdominal hooded hooks with shorter shafts than in thorax; branchiae absent; pygidium with a short, median anal cirrus.

Genus – *Maldane* Grube.

Characters of the genus are same to those of the species mentioned bellow.

21. *Maldane sarsi* Malmgren, 1867.

Cephalic keel convex, arched; rim divided into three parts by two deep lateral notches. nuchal grooves short, anal plate oval, slanting, with the rim notched on each side; anus dorsal; ante-anal segments achaetous. anterior segments without collar. ventral setae absent on the first segment. dorsal setae of three kinds; uncini from the second setigerous segment; glandular belts; Tube coated with mud.

Genus – *Axiothella* Verrilli.

The characters of the genus are same to those of the species mentioned bellow.

22. *Axiothella obockensis* Gravier, 1906.

A cephalic rimmed plate; pygidium funnel shaped, fringed with cirri; without collar; denticulated uncini from the first setigerous segment; tube membranous coated with sand.

Genus – *Owenia* Chiaje, 1814.

Prostomium bearing a branchial laciniate membranous; buccal segment achaetous; the first three setigerous segments long and without uncini; dorsal setae slender, spinous; uncini bidentate; pygidium bilobed; glandular belts and spinning glands present.

*23. Owenia fusiformis* Chiaje, 1814

Uncini with an elongated manubrium and a curved hook with two parallel teeth; the two ante-anal segments without dorsal setae; tube membranous, open and tapering at both ends, coated with overlapping sand grains and flat bits of shells, imbricated.

## ROLE OF BENTHOS OF MANGROVES IN BIOMASS INCREASE, FISH PRODUCTION AND ITS COMMERCIAL IMPORTANCE

It is well known that the floral and faunal biomass production has its direct relation with the fishery resource of any aquatic system. It is not only that the biomass has a direct link with the fishery as an important source of food for fishes; but it has also an indirect contribution in the form of the major source of inorganic nutrients for the production of phytoplankton and zoo- plankton. Just like the benthic faunal impact on the major biomass increase in specific areas, the epiphytic algae also forms a major source of feed for fishes and other animals as well as their larval forms. Some of the recent findings have also shown that the gametes and spores released by major algae form an important food for bivalves, fishes, crustaceans and almost all larval forms of animals just like the nano plankton and other types of phytoplankton in the aquatic environment. Because of this the mangrove ecosystems and its associated benthic and epiphytic fauna and flora serve as a nursery area for the larvae and juveniles of fishes, crustaceans, bivalves etc.

As mentioned earlier, mangroves have their own complexity of floral and faunal groups but there are parallelism in the structural configuration of the mangrove locality. In spite of this, it is possible to make generalizations based on the earlier observations on the benthic faunal and floral distributions in this peculiar environment.

### Potential groups contributing the benthic biomass

Among the potential groups, Coelenterates, Annelids (Polychaetes) Molluscs especially the bivalves, gastropods and Crustaceans are the major biomass producers. Similarly the epiphytic algae also contribute to the biomass production. Some of the polychaete species under the families like *Nereidae, Nephthydae, Onuphidae, Eunicidae, Spionidae, Maladanidae, Sabellariidae* etc are the major biomass producers among Annelids and these form an important food for different species of prawns and fishes. Similarly Bivalves like Mussels, Clams, Rock oysters, Edible oysters etc contribute a major share in the benthos of mangrove ecosystems.

Algae like *Ulva, Spp., Chaetomorpha Spp, Hypnea Spp, Enteromorpha Spp, Gracilaria Spp*. etc are some of the dominent biomass producer in this system.

The enormous quantities of larvae released by the animals and the reproductive bodies released by the algae enrich the system as a productive nursery area with sufficient sources of food for the young ones of commercially important Fishes, Crustaceans and Mollucs of export value.

### Recycling of Nutrients from the benthic habitat

The burrowing bivalves and gastropod molluscs, polychaetes, coelenterates etc have a ploughing effect on the bottom substratum and it helps in the release of nutrients from the sub soil.

In addition to this the organic decay of these animals also enriches the nutrient potential of the aquatic environment for increased production of phytoplankton and zooplankton and they in turn increases the productions of Ichthyofauna.

Above findings are some of the areas in which further investigations are to be conducted and as a result it can be established that mangrove and its benthos function as a very useful recycling system for increased production of resources of commercial value in the aquatic environment.

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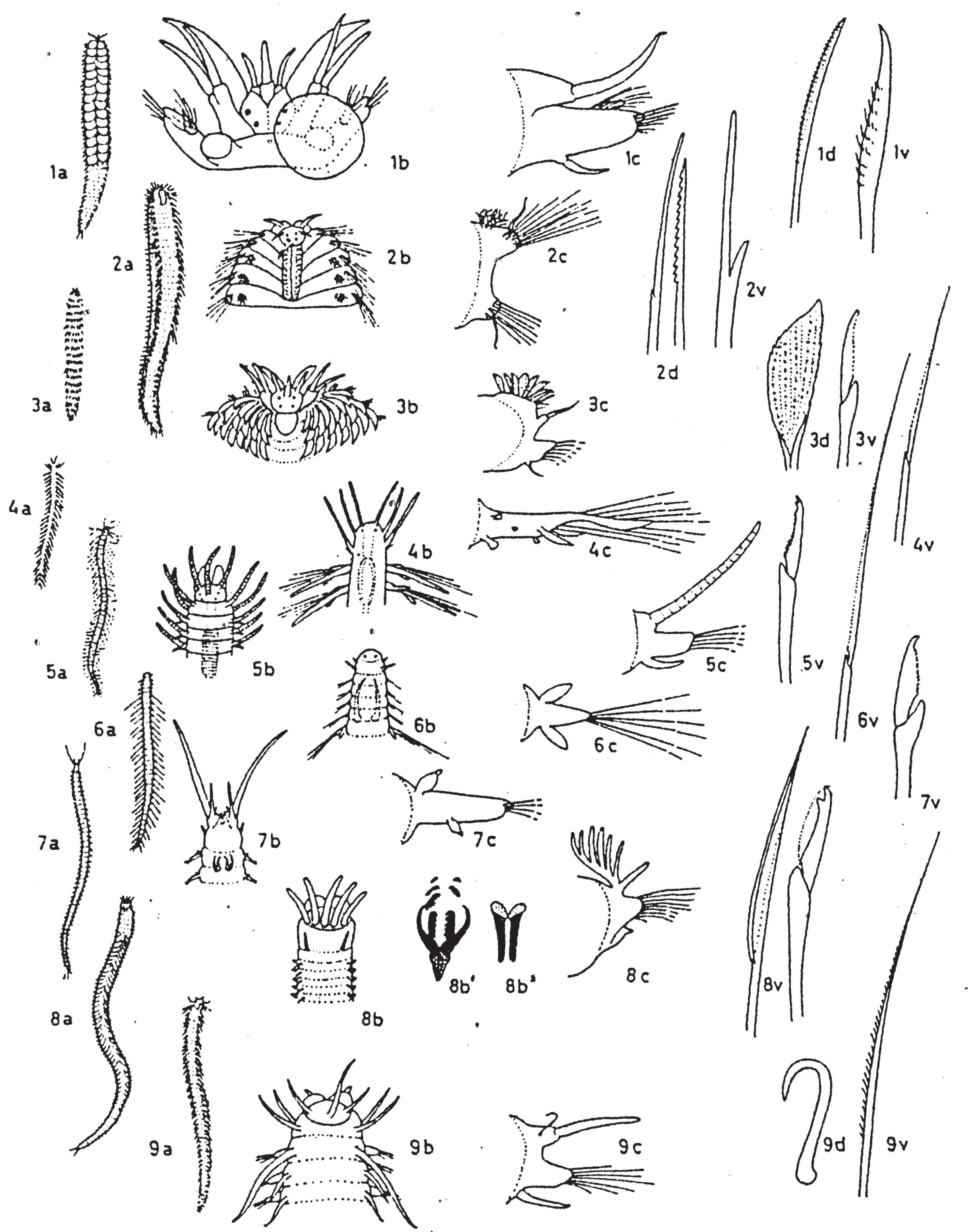



**Fig. 1. Illustrations of Family Characters** (After Day, 1967) 1a to 9a Entire worm. (1a) Aphroditidae. (2a) Amphinomidae. (3a) Palymridae. (4a) Pontodoridae. (5a) Syllidae. (6a) Iospilidae. (7a) Pisionidae. (8a) Eunicidae. (9a) Pilargidae.

1b to 9b Head of the above mentioned families

1c to 9c Foot of the above mentioned families

1d, 2d, 3d & 9d Notoseta of the above mentioned families

1v, 9v Neuroseta or seta of uniramous parapodium of the above mentioned families

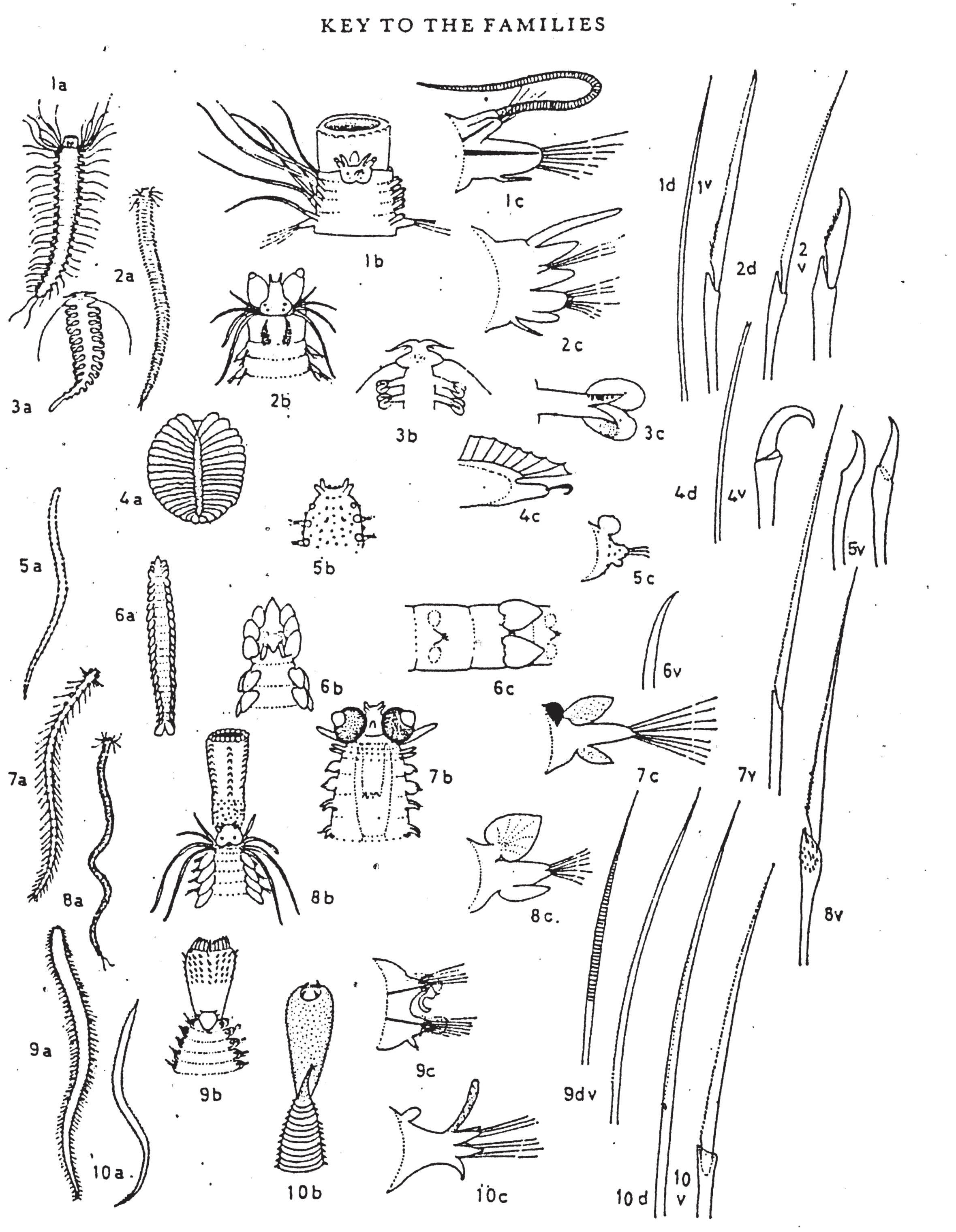



**Fig. 2. Illustrations of Family Characters** (After Day, 1967) 1a to 10a Entire worm. (1a) Hesionidae. (2a) Nereidae. (3a) Tomopteridae. (4a) Sphintheridae. (5a) Sphaerodoridae. (6a) Typhloscolecidae. (7a) Alciopidae. (8a) Phyllodocidae. (9a) Nephtyidae. (10a) Glyceridae.

1b to 3b & 5b to 10b Head of the above mentioned families

1c to 10c Foot of the above mentioned families

1d, 2d, 4d, 9d & 10d Notoseta of the above mentioned families

1v, 2v & 4v to 10v Neuroseta or seta of uniramous parapodium of the above mentioned families

KEY TO THE FAMILIES

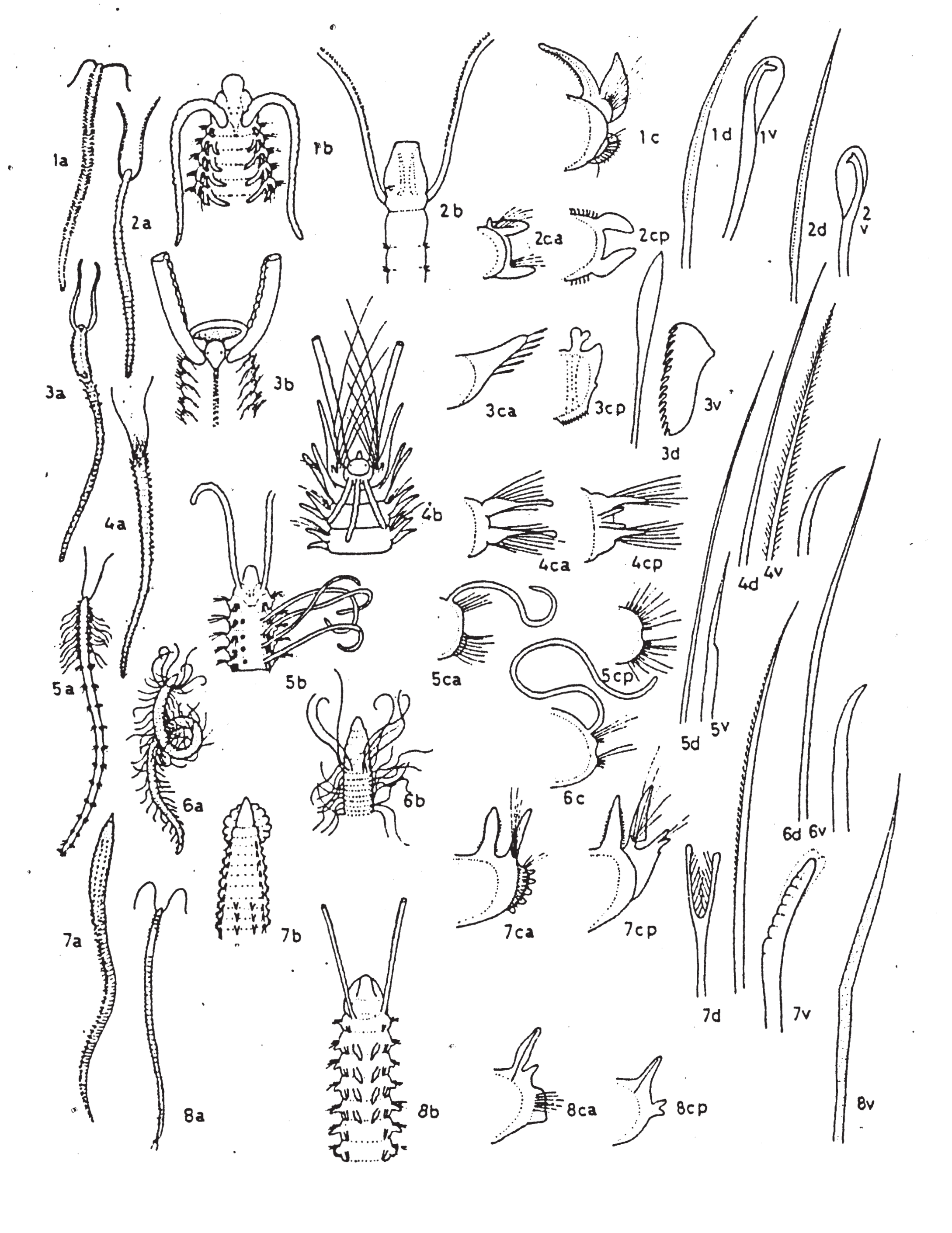



**Fig. 3. Illustrations of Family Characters** (After Day, 1967) 1a to 8a Entire worm. (1a) Spionidae. (2a) Magelonidae. (3a) Chactopteridae. (4a) Trochochaetidae. (5a) Heterospionidae. (6a) Cirratulidae. (7a) Orbiniidae. (8a) Aspitobranchidae.

1b to 8b Head of the above mentioned families

2ca to 5ca, 7ca & 8ca Anterior Foot of the above mentioned families

2cp to 5cp, 7cp & 8cp Posterior Foot of the above mentioned families

1c & 6c Foot of the above mentioned families

1d, to 7d Notoseta of the above mentioned families

1v to 8v Neuroseta of the above mentioned families

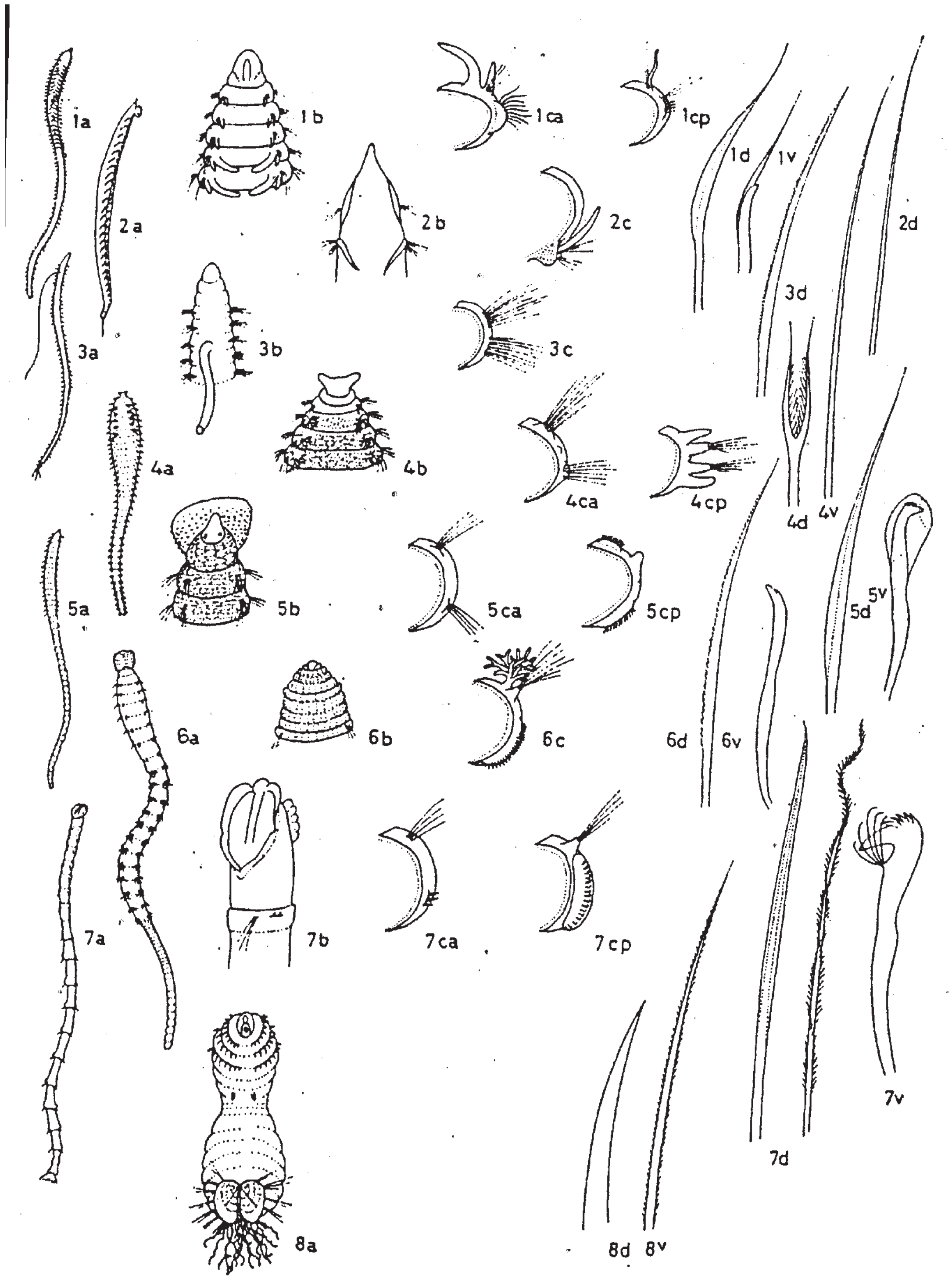



**Fig. 4. Illustrations of Family Characters** (After Day, 1967) 1a to 8a Entire worm. (1a) Paraonidae. (2a) Opheliidae. (3a) Cossuridae. (4a) Scalibregmidae. (5a) Capitellidae. (6a) Arenicolidae. (7a) Maldanidae. (8a) Sternaspidae.

1b to 7b Head of the above mentioned families

1ca, 4ca, 5ca & 7ca Anterior Foot of the above mentioned families

1cp, 4cp, 5cp, 7cp Posterior Foot of the above mentioned families

2c, 3c & 6c Foot of the above mentioned families

1d, to 8d Notoseta of the above mentioned families

1v & 4V to 8v Neuroseta of the above mentioned families

KEY TO THE FAMILIES


**Fig. 5. Illustrations of Family Characters** (After Day, 1967) 1a to 8a Entire worm. (1a) Oweniidae. (2a) Flabelligeridae. (3a) Sabellaridae. (4a) Pectinariidae. (5a) Ampharetidae. (6a) Teribellidae. (7a) Sabellidae. (8a) Serpulidae.

1b to 6b Head of the above mentioned families

1c to 4c Foot of the above mentioned families

5ca to 8ca Anterior Foot of the above mentioned families

5cp, 7cp & 8cp Posterior Foot of the above mentioned families

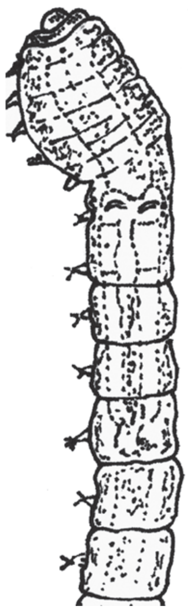
1d, to 8d Notoseta of the above mentioned families

3h Palea from operculum

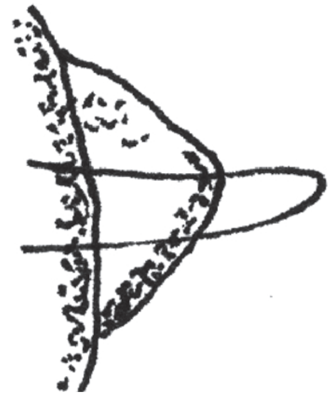
1t, 3t, 4t & 8t Tube

1v to 8v Neuroseta of the above mentioned families

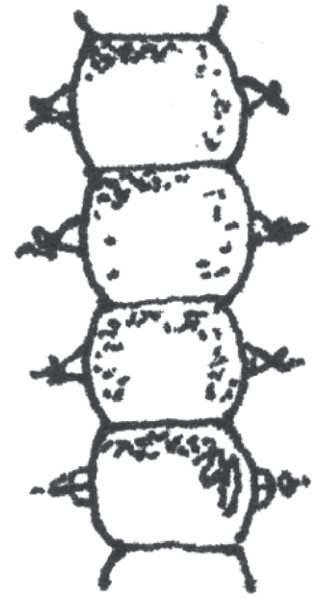
***Talehsapia annandalei*** **(After Day, 1967)**



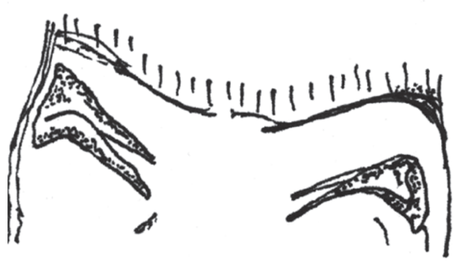
Anterior end compressed
Showing the jaw



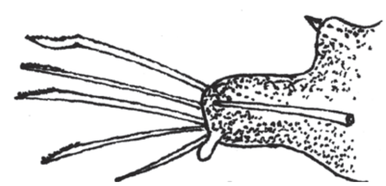
Dorsal ramus and stout
Acicular bristle



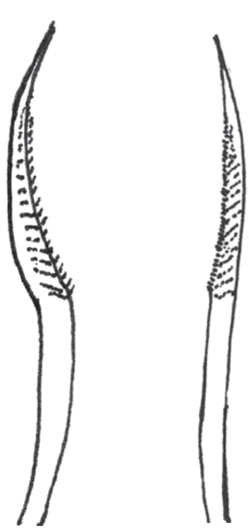
Segments of posterior end



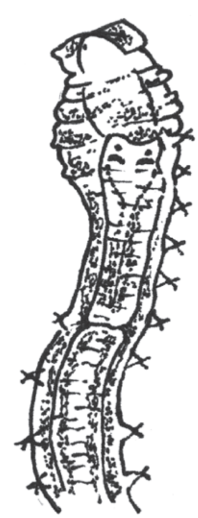
Jaws, dorsal view



Foot



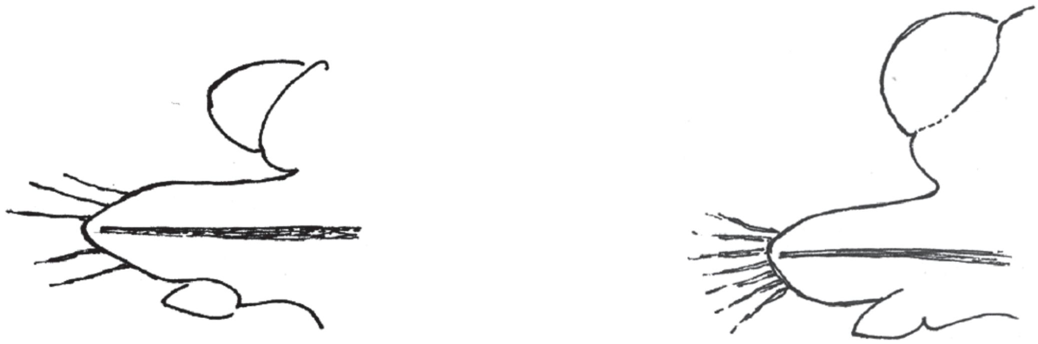
Hidpid setae



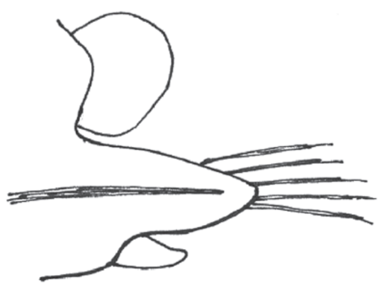
Anterior end

**Fig. 6.**

***Eteone barantollae*** **(After Day, 1967)**



**Anterior foot front and back view**



Foot from mid-body

Posterior dorsal cirrus

***Lumbriconereis heteropoda***

Hook

Hind foot

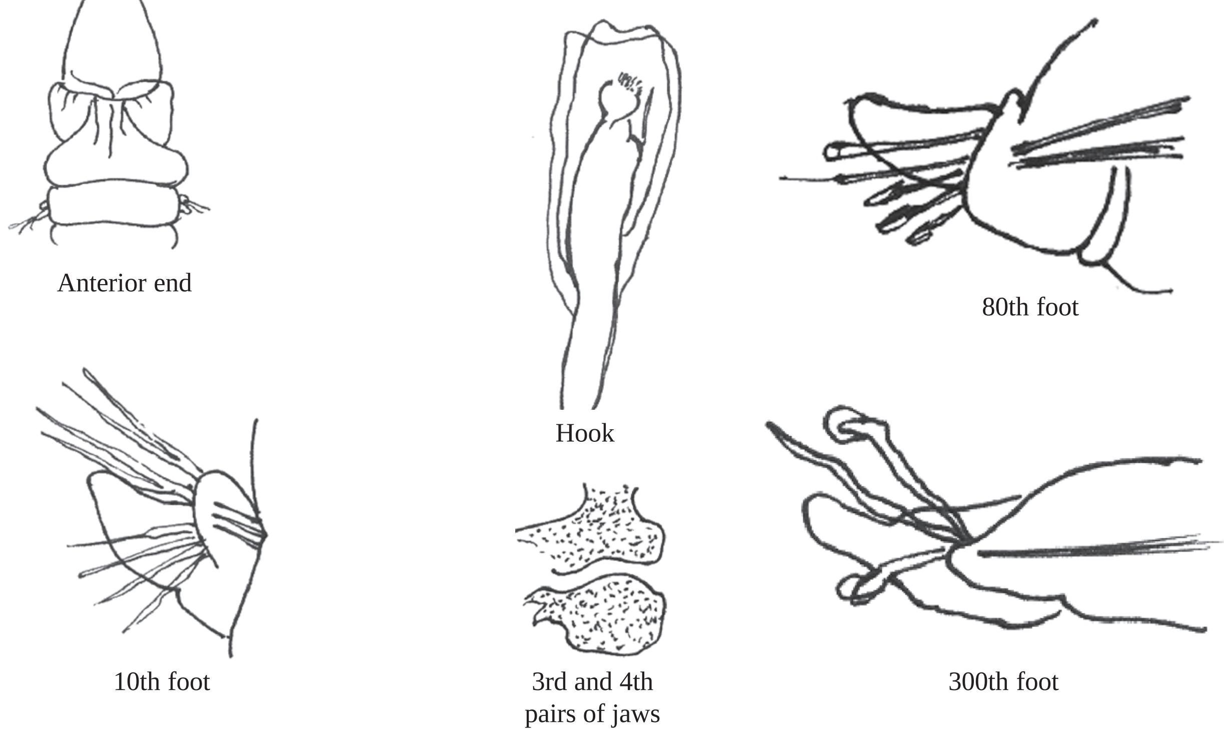
***Mastobranchus indicus***

Tip of a long hook
from the ventral division
of the 11th foot

Tip of the dorsal hook
from the 14th foot

**Fig. 7.**

***Lumbriconereis polydesma*** **(After Day, 1967)**




***Axiothella obockensis***

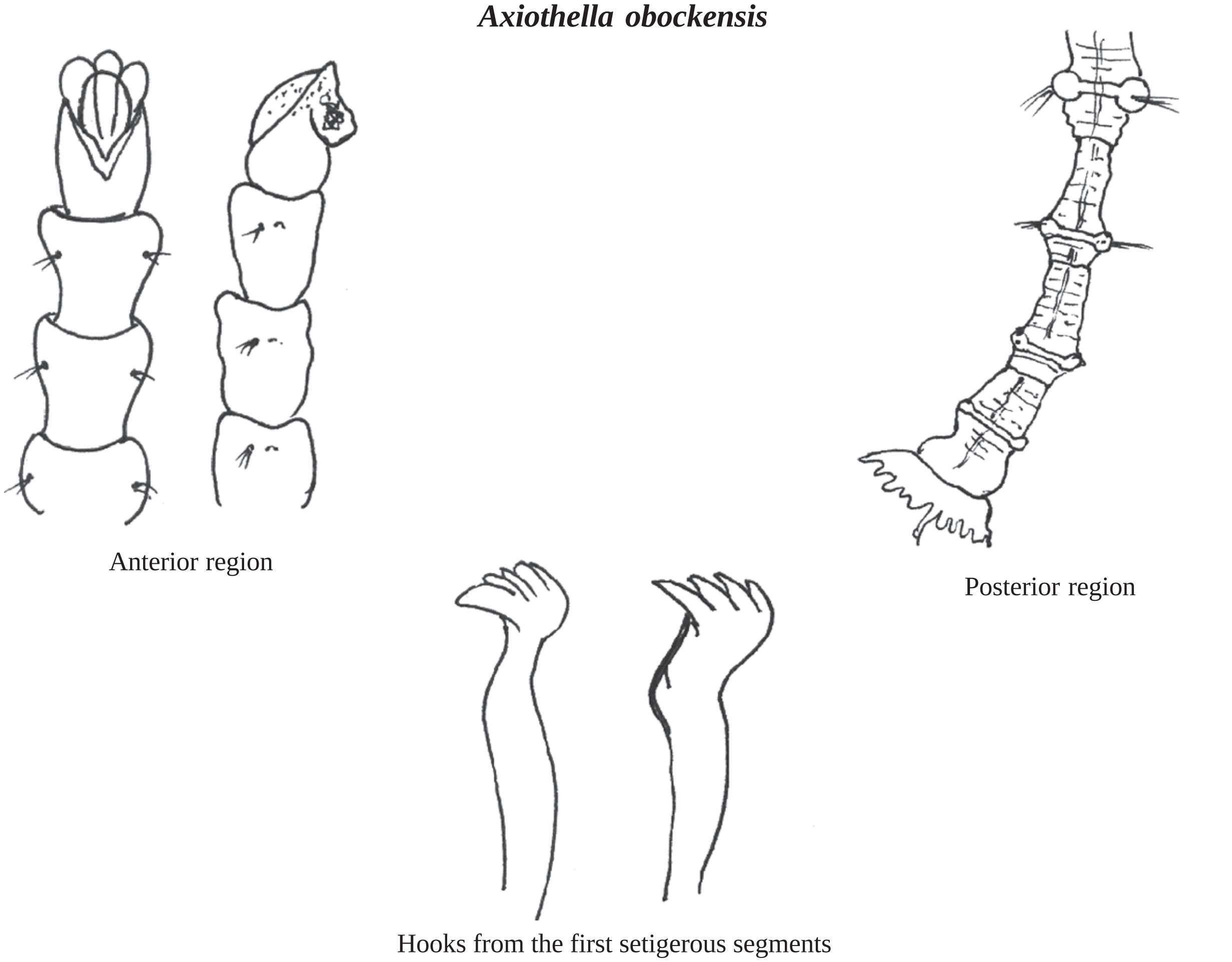



**Fig. 8.**

***Maldane sarsi* (After Day, 1967)**

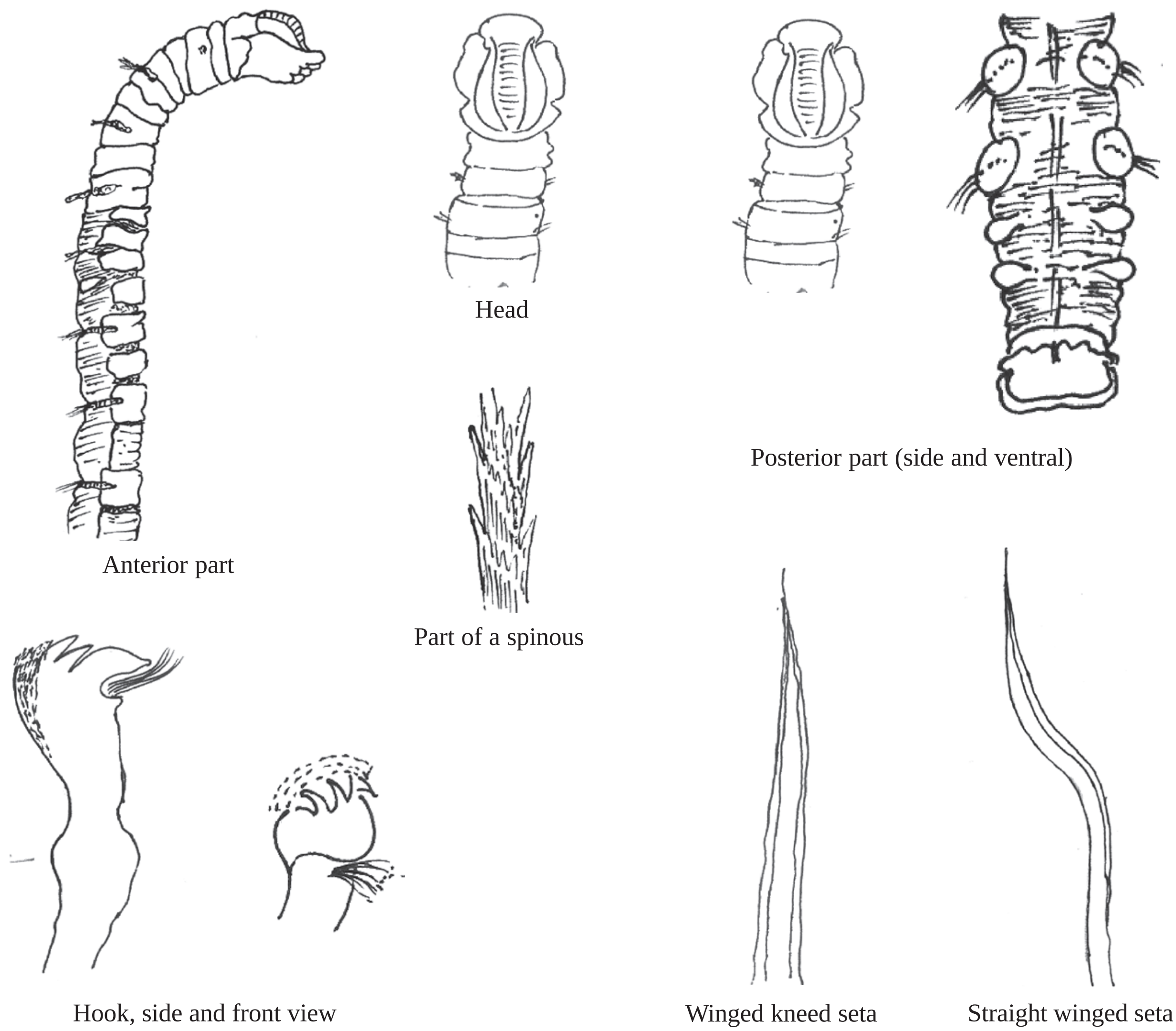
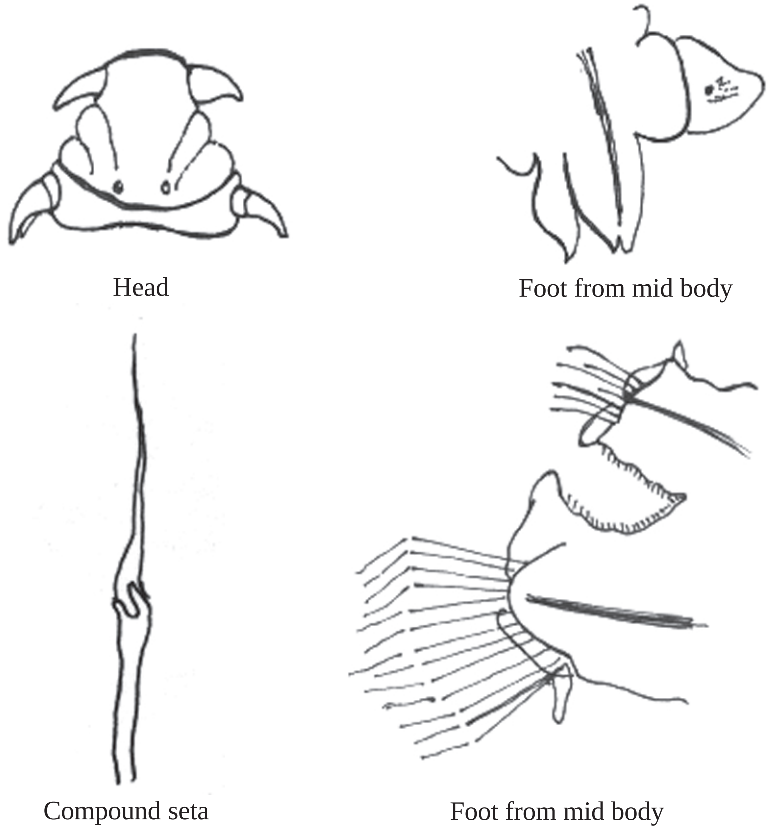


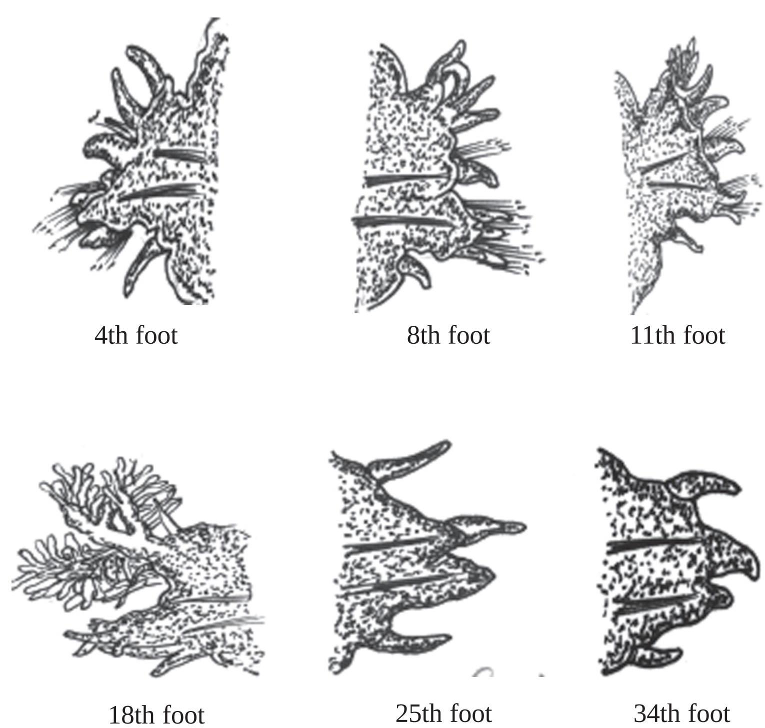

**Fig. 9.**

***Eteone ornata*** **(After Day, 1967)**




***Dendronereides aestuarina***


***Dendronereides heteropoda***




***Glycera alba***

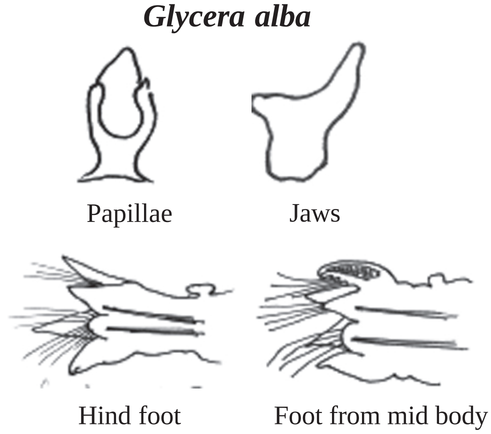
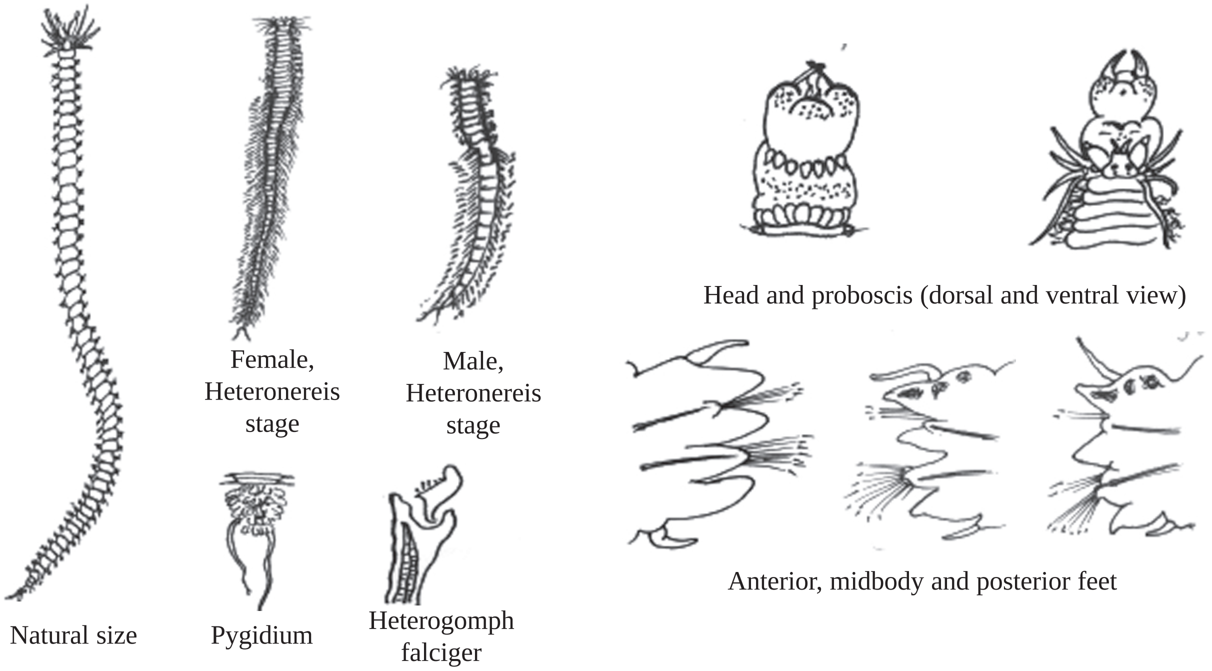
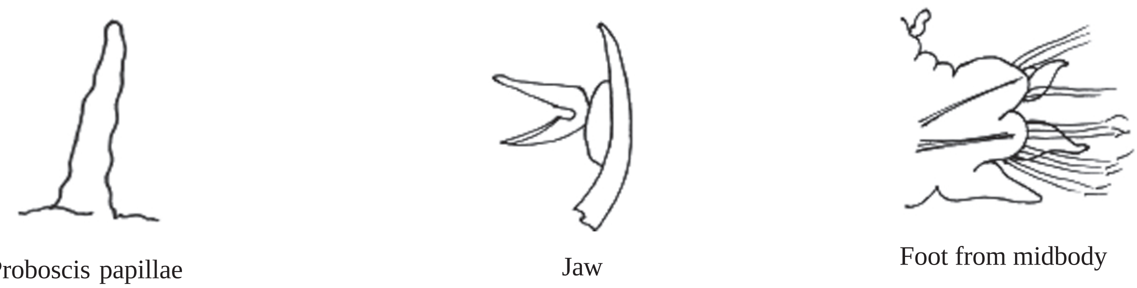



**Fig. 10.**

***Perinereis cultrifera* (After Day, 1967)**




***Glycera tesselata***




***Neanthas chingrighanttensis***

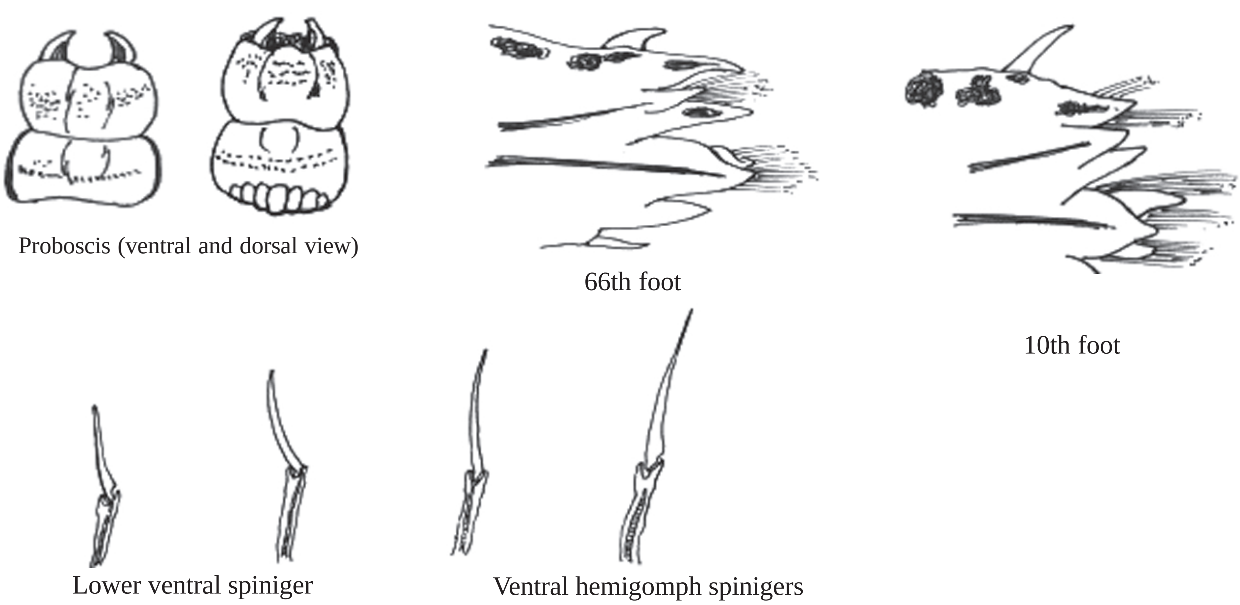
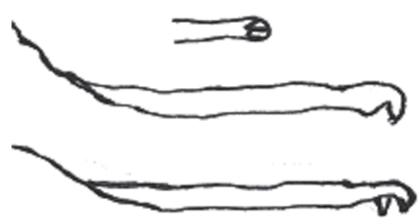



**Fig. 11.**

## *Owenia fusiformes* **(After Day, 1967)**

Natural size

Tube, natural size



Unicini, front and side view

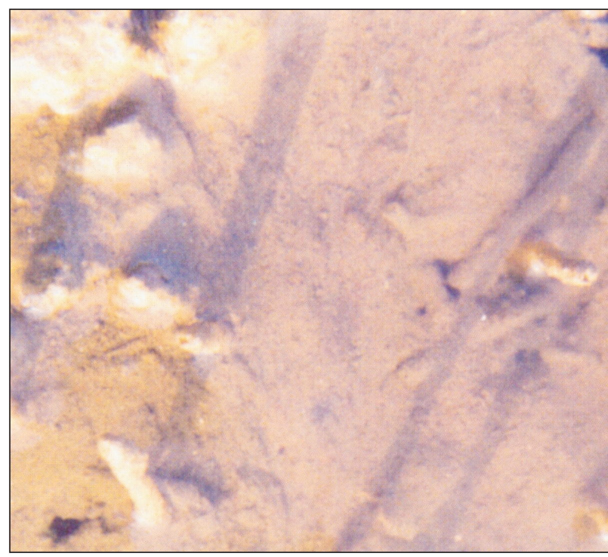
Dorsal bristle

Head with mouth

**Fig. 12.**

**(After Day, 1967)**

Bioturbation structure of the polychaete *Diopatra cuprea*



Bioturbation structure of the polychaete *Maldane sarsi*

Bioturbation structure of the polychaete *Owenia sp.*

**Fig. 13.**

# Sea-Anemones

Gurudas Chakravarty, S. K. Chakraborty, G. P. Kumaraswamy Achary and S. Dam Roy

Actiniarians are popularly called ‘sea-anemones’ because of their flower-like appearance of the expanded oral disc. They are very common animals of the sea-shore and muddy intertidal belt of estuary. They belong to the Phylum Cnidaria having solitary, cylindrical body. The body is divided into oral disc, column and base. Different workers like- Annandale (1907&1915), Carlgren (1925), Panikkar (1936), Parulekar (1968), Seshaiya and Cuttres (1971), Misra (1975&1976), Misra and Soota (1981), Bairagi (1998) etc. had worked on sea-anemones in Indian waters. Altogether 20 species under 17 genera belong to 10 families have been recorded from India. Among these only 7 species are reported from West Bengal but Bairagi (1998) had confirmed the occurence of 9 species under 7 genera and 5 families from Hoogly-Matla estuarine area of West Bengal.

**Morphological characters : general scientific terms**

***Acontia:*** These are thin threads attached at one end to mesenteries, as a rule below the filaments, while the other end free and laden with extra-ordinary numerous nematocysts of variable categories.

***Basilar muscles:*** In forms with a pedal disc, the parietal muscles, found on both faces of the septa, running out onto the disc more or less parallel to it.

***Physa:*** The aboral ampullaceous end of certain Athenaria is known as physa.

***Scapus:*** This is the principal and longest zone of the column - often provided with tentacles or tubercles.

***Scapulus:*** A thick walled zone above the scapus differing from it in histological construction and general appearance.

***Capitulum:*** Upper short delicate, thin wall region of the column.

***Nematocysts:*** Stinging capsules, the thread of which shows several types of structure: a) *atrichs* - thread without a differentiated basal shaft and with barbs, smooth. b) *holotrichs* - thread without a differentiated basal shaft but with barbs along its whole length. c) *basitrichs* - thread without shaft but with barbs at its base only.

***Actinopharynx:*** The tube which leads from the mouth into the coelenteron.

***Sphincter:*** The endodermal circular muscles of the column are often accumulated at or near the margin and form a sphincter which is endodermal or embedded in the mesogloea, when it is called a mesogloeal sphincter.

**Taxonomy of different species of Actiniaria (Sea-anemones) in mangroves**

| **Species** |
|---|
| **Phylum - Cnidaria**<br>**Class - Anthozoa**<br>**Order - Actiniaria**<br>**Family - Edwardsiidae** |
| *i)Edwardsia jonesii* Seshaiya & Cuttress |
| **Family- Haliactiidae** |
| i)*Pelocoetes exul* Annandale |
| ii) *Phytocoeteopsis ramunii* Panikkar |
| **Family-Diadumenidae** |
| i) *Diadumene schilleriana* (Stoliczka) |
| **Family- Actiniidae** |
| i) *Paracondylactis indica* Dave |

**Phylum – Cnidaria :**

1. The Cnidarians exist in two forms - *Polyp* (representing asexual phase) and *Medusa* (representing sexual phase). Polyp is tubular and

usually remains fixed at aboral end. Medusa is fre-swimming, umbrella -like.

2. Highly specialised intracellular structures called *nematocysts* are present.
3. Presence of a single internal *coelenteron.*
4. Presence of only one permanent aperture - the mouth which also functions as anus.

**Class – Anthozoa :**

1. They exist only in *polyp* form.
2. Stomodaeum is strongly developed and possesses siphonoglyphs, e xtending between the stomodaeum and the body-wall there are mesenteries.
3. Mesoglea is well-developed with fibrous connective tissue.

**Order – Actiniaria :**

1. Numerous tentacles and mesenteries are usually present in multiples of six.
2. Skeleton is absent.

**Key to the families of Actiniaria:**

1. Basilar muscles present………2

   Basilar muscles absent……….3
2. Acontia present ---------------- **Diadumenidae.**

   Acontia absent ----------------- **Actiniidae.**
3. Acontia present ---------------- **Haliactiidae.**

   Acontia absent ----------------- **Edwardsiidae.**

**Family - Edwardsiidae.**

Genus - *Edwardsia* Quatrefages, 1842

Body divided into physa, scapus, scapulus and capitulum; scapus long with batteries of nematocysts sunk in the mesogloea; tentacles at least 12, shorter or longer; ventral siphonoglyph weak.

*i) Edwardsia jonesii* Seshaiya & Cuttress, 1971.

Tentacles 12, long, smooth and arranged in two cycles of 6 each; body distinctly divided into capitulum, scapulus, scapus and inflatable physa without cuticle; capitulum thin-walled, almost transparent, smooth and without cuticle; scapus thick-walled, covered with thick shaggy rusty-red cuticle; actinopharynx with 8 longitudinal ridges, siphonoglyph indistinct.

**Family - Haliactiidae**

Genus - *Pelocoetes* Annandale, 1915.

Elongated vermiform body; column divided into capitulum, scapus and physa. Scapus with longitudinal rows of warts; distinct sphincter absent; Actinopharynx long; upper part of capitulum and oral disc thrown out into 6 long outgrowths (pedicels) each bifurcating two or three times.

ii) *Pelocoetes exul* Annandale, 1915

Basal disc reduced, bluntly tapering and without physa; column elongated; longitudinal rows of nematocyst batteries alternate with cinclides on column; tentacle’s branches hexamerously arranged (6+6+12+24+48, the last cycle more or less complete); oral disc lobed.

Genus - *Phytocoeteopsis* Panikkar, 1936.

Body vermiform, divisible into 3 distinct regions, capitulum, scapus and physa - like base; column elongated, smooth and without suckers or cuticle; sphincter absent; oral disc with redial muscles; tentacles numerous, arranged in five to six cycles; acontia well developed.

iii) *Phytocoeteopsis ramunnii* Panikkar, 1936.

Tentacles 96, arranged in five cycles; base usually reduced, physa-like and without ectodermal cinclides; column thin and smooth; capitulum narrow, scapus long,thick, very broad above and vermiform below.

**Family - Diadumenidae**

Genus - *Diadumene* Stephenson, 1920.

Body divided into scapus with cinclides and capitulum with collar; tentacles long and numerous, inner tentacles thicker than the other tentacles; basal disc well developed; distinct sphincter absent.

iv) *Diadumene schilleriana* (Stoliczka, 1869).

Body very short, 12-19 mm in length and diameter greater than that of column and provided with longitudinal rows of warts; basal disc strong and adhesive; column divided into scapus and capitulum; tentacles long, numerous, more or less regularly arranged and inner tentacles thicker than the outer; distinct sphincter absent.

**Family - Actiniidae**

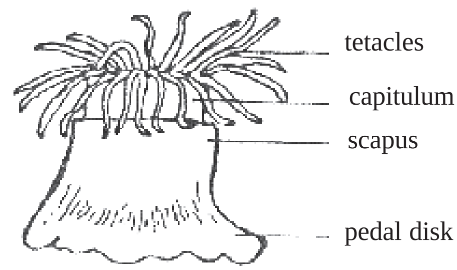
Genus - *Paracondylactis* Carlgren, 1934.

Body elongated and pedal disc narrow; column smooth, sometimes with nematocysts; sphincter diffuse; tentacles hexamerously arranged.

v) *Paracondylactis indica* Dave, 1957.

Column elongated and tapering; pseudospherules present on column; pedal disc flattened but distinct; tentacles 96, white in colour, arranged in five cycles.

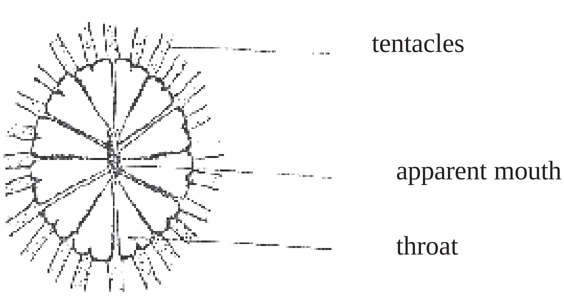

Contracted with acontia



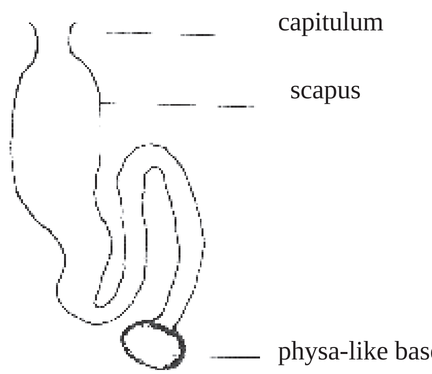

Expanded

***Diadumene schilleriana***

***Paracondylactis indica* (bioturbation structure)**




The first whorl of tentacles




General shape of the column

***Phytocoeteopsis ramunnii***

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# Crustacea (Crab)

**S. K. Chakraborty, Gurudas Chakravarty, Sunirmal Giri, S. Dam Roy and George J. P.**

Brachyuran crabs, a bioenergetically significant group constitute one of the most dominant macrobenthic faunal components in all the mangrove ecosystems of the world. Several species of commercially important crabs like - *Scylla serrata* occur in mangroves. Brachyuran crabs play significant role to maintain the steady state condition of mangrove ecosystems several ways. The feedig activities of detritivore crabs such as - *Uca, Macrophthalmus, Dotilla, Sesarma* etc. help in the degradation of organic matter, especially mangrove litters and decaying woods. They also influence the functioning of mangrove ecosystems as burrowers since their repeated burrowing and reburrowing activities enhance the soil aeration, mixing of different soil profiles, nutrient cycling, maintaining of fluidity etc. (Montague, 1980, 1982 ; Bertness, 1985). Furthermore, crabs create a wide variety of *bioturbation* structures which are very significant for trapping sediments and mangrove seeds (Choudhury and Choudhury, 1994). In India several taxonomic works on estuarine and mangrove brachyuran crabs have been done (Chakraborty *et al.*,1986; Mandal and Nandi, 1989; Chakraborty and Choudhury, 1992; Dev Roy and Das, 2000 etc.). A total of 55 species of brachyuran crabs under 31 genera have been reported earlier from the mangrove habitats of India (Dev Roy and Das, 2000). Eighteen species of brachyuran crabs under 9 genera and 4 families were identified from Sundarbans Mangrove Ecosystems (Chakraborty and Choudhury, 1992).

**Identification characters :**

**General scientific terms**

***Cephalothorax*:**

This is the anterior rigid part of the crabs, made up of six head segments and 8 thoracic segments, all fused together.

***Carapace* :**

The entire body of a crab is covered dorsally by a tough cuticle, called carapace or shell of crabs. The carapace is composed of fused **tergites.** The anterior portion of carapace in between the orbits is known as **front.** Lateral sides of carapace are often differentiated into antero and posterio-lateral borders. The dorsal surface of carapace is usually divisible into several regions such as **gastric, cardiac, intestinal** and **branchial.**

***Stermites* -** Cephalothorax is covered ventrally by stermites, its lines of fusion are very prominent. Stermites extend into the body as folds, called **apodemes**.

***Pleuron* -** The exoskeleton that covers the lateral sides of carapace is called **pleuron.**

***Pleural fold* -** The margin of the carapace extending on either side is known as **Pleural fold** which is separated into an anterior **pterygostomial region** (also called jugal region) and a posterior **branchiostegite** which is continuous with the carapace forming the external covering of the gill chamber.

***Appendages*:**

They are of three types **cephalic appendages, thoracic appendages** and **abdomen**.

***Cephalic appendages* -** It includes **antennule or first antenna, second antenna, mandible, first maxilla and second maxilla.**

***Scaphognathite* -** Exposed second maxilla develop into a lateral flap-like structure, called **scaphognathite.**

***Thoracic appendages* -** It includes **maxillipeds, chelipeds and walking legs.**

***Maxillipeds* -** There are three pairs. Biramous maxillipeds bearing **epipods** which serve to clean the gills.

***Chelipeds*** **-** These are also known as first leg. They are uniramous, paired appendages and consist of **coxa, basis, ischium, arm or merus, weist or carpus** and the **chela** which is made up of **palm** (also called **hand or manus**) and fingers of upper finger is known as dactylus or movable finger and lower one is fixed finger (also called **thumb** or immovable finger or **pollex**).

***Walking legs*** **-** These are 4 pairs and all are long, pointed, uniramous and jointed structure. Each leg is made up of seven segments, *viz.* **coxa, basis, ischium, merus, carpus, propodus** and **dactylus.**

***Abdomen*** **-** The abdomen of a crab is a flap-like structure and usually made up of six segments. The abdomen is articulated ventrally to the cephalothorax with a groove formed by somites. It is much broader in female than in male. The abdominal appendages and pleopods are rudimentary and in both sexes six pairs of pleopods are absent, while only two pairs of copulatory stylets formed by first and second pleopods are found in males. Anus is located at the terminal end of the last abdominal segment, at the junction with telson.

**Brachyuran Crabs from Mangroves**

| |
|---|
| **Phylum- Arthropoda**<br>**Sub-phylum - Mandibulata**<br>**Class - Crustacea**<br>**Order- Decapoda**<br>**Section - Brachyura**<br>**Family- Portunidae** |
| *i) Scylla serrata* (Forskal) |
| *ii) Portunous pelagicus* (Linnaeus) |
| **Family- Ocypodidae** |
| i) *Ocypoda macrocera.* Edwards. |
| ii) *O. ceratophthalma* (Pallas) |
| iii) *Uca acuta acuta* (Simpson) |
| iv) *U. (Celuca) lactea annulipes* (H. Milne Edwards) |
| v) *U. triangularis bengali* (Nobili) |
| vi) *U. dussumieri dussumieri* (H. Milne Edwards) |
| vii) *Dotilla blanfordi* Alcock |
| viii) *Dotillopsis brevitarsis* (De Haan) Kemp |
| ix) *Scopimera globosa* De Haan |
| x) *Macrophthalmus pectinipes* Guerin |
| **Family- Grapsidae** |
| i) *Sesarma chiromantes bidens* (De Haan) |
| ii) *S. taeniolatum* White |
| iii) *S. longipes* Krauss |
| iv) *S. pictum* De Haan |
| v) *Metaplax intermedia* de Man |
| vi) *M. crenulata* Gerstaecker |
| Vii) *M. distincta* Edwards |
| **Family - Calappidae** |
| i) *Matuta victor* Grabricius |
| ii) *M. lunaris* (Forskal) |
| **Family - Maiidae** |
| i) *Doclea japonica* Ortmann |

**Phylum Arthropoda:**

1. Body is segmented and covered by chitinous cuticle.
2. Each body segment bears paired externally jointed appendages.

**Sub-phylum Mandibulata:**

1. Body is divided into two or three parts.
2. Appendages on the third head segment are modified as mandibles for chewing or grinding food.
3. Usually compound eyes are present; retinula of compound eyes consist of 8 cells.

**Class Crustacea:**

1. Body divided into cephalothorax and abdomen.
2. Head bears two pairs of preoral and three pairs of postoral appendages.
3. Uniramous, one or two pairs of antennae, other appendages are biramous.
4. Biramous appendages are either phyllopodium or stenopodium.

**Order Decapoda:**

1. First 3 pairs of thoracic limbs form maxillipeds.
2. Carapace well developed usually enclosing gill chambers on sides of cephalothorax.
3. Gills usually in three series present on thorax.

**Section Brachyura:**

1. Dorso-ventrally flattened cephalothorax
2. Antennae very small
3. Presence of small abdomen and europod.

**Diagnostic characters of different families of Brachyura:-**

**Family- Portunidae.**

The fifth pair of legs are modified for swimming and usually has the propodite and dactylus; Singularly broad thin and paddle - like.

**Family - Ocypodidae.**

Amphibious, littoral and estuarine crabs, burrowing and commonly gregarious. The palp of the external maxillipeds is coarse and articulates at or near the antero-external angle of the merus: the exognath is generally slender and often more or less concealed; The interantennular septum is generally broad; The orbits occupy the whole anterior border of the carapace out side the front and their outer wall is often defective. The buccal cavern is usually large and a little narrower in front than behind, the external maxillipeds are foliaceous; The abdomen of the male narrow; Male opening sternal.

**Family - Grapsidae**

Mainly estuarine but some species are found in freshwater and brackish water border zones. The palp of the external maxillipeds articulates either at the antero-external angle, or at the summit or at the middle of the anterior border of the meros; the exognath is either abnormally slender or broad. The inter antennular septum is very broad; The orbit divided into two fossae. Male openings sternal.

**Family- Calappidae**

Carapace is of the ordinary brachyurous shape; The afferent branchial openings are found infront of the bases of the chelipeds; The antennae are small; The vasa deferentia perforate the bases of the fifth pair of legs.

**Diagnostic characters of different species**

**Genus - *Scylla* De Haan,1833**

Carapace broad, transverse, somewhat convex with an almost even surface; front cut into four teeth; antero-lateral borders arched oblique and cut into nine subequal teeth (including the outer orbital tooth), postero-lateral margin shorter than the antero-lateral; Basal joint of antenna short, broad, its antero-external angle forming a lobule lying in the orbit, flagellum quite long and lodged in the orbital hiatus; Antennules folding transversely; Chelipeds massive; wrist and palm smooth, without ridges; Legs stout, moderately compressed; merus and carpus of the last pair shortened and broadened, dactyls typically foliaceous for swimming; Male abdomen triangular, five segmented, 3$^{rd}$-5$^{th}$ terga fused, first tergum much concealed below the carapace.

1. *Scylla serrata* (Forskal, 1755)

   Antero-lateral border of carapace cut into 9 sharp acuminate teeth of nearly equal size; Arm of the larger cheliped adorned with 3 spines on the anterior boarder; Leg joints unarmed.

**Genus – *Portunus* Weber, 1795**

Carapace usually broad and depressed or little convex; front cut into three to six – usually four teeth; antero-lateral borders cut into nine teeth (including the outer orbital angle) of which the 9$^{th}$ may be enlarged or not; antennules fold transversely; flagellum stands in the orbital hiatus; chelipeds longer, usually much longer than any of the legs and massive; legs compressed; abdomen of the male is five-jointed.

2. *Portunus pelagicus* (Linnaeus, 1758)

   Whitish or pale bluish irregular spots present on the carapace; the granulation on the dorsal surface is very prominent; a spine present at the far end of the posterior border of the arm of chelipeds.

**Genus - *Ocypoda* Fabricus, 1798**

Coloured crabs - colours are red, yellow and whitish in different stages of development; Carapace deep, square or subquadrilateral, broader than long, moderately convex; Afferent branchial opening thickly fringed with setae between bases of 2$^{nd}$ and 3$^{rd}$ pair of legs; flagellum of antenna small and folding obliquely, inter-antennular septum broad; front narrow; Chelipeds very unequal in both sexes.

3. *Ocypoda macrocera* Edwards,1861

   Broad carapace; upper orbital margin oblique; the raised marginal row of granules on the external maxillipeds is less pronounced; the fingers of the smaller cheliped are lamellar upto the tips, which are broad and blunt, not pointed; stridulating ridge entirely of striae and less hairy.

4. *Ocypoda ceratophthalmus creatophthalma* (Pallas, 1772)

   Carapace square and posterior elegantly beaded; upper orbital margin a little oblique; eyestalk prolonged beyond the eye into a style of variable length; stridulating ridge of large manus with tubercles gradually passing into striae with hairs; two rows of thick hairs on anterior surface of manus of first two pairs of legs; fingers (dactyl) of both chelipeds pointed at tip.

**Genus - *Uca* Leach, 1814**

Carapace deep, subquadrilateral or subhexagonal, broader than long, surface usually smooth, antero-lateral angles generally pointed; Antenna with well developed flagella; Antennules very small, folded obliquely orbits deep, little sinuous and oblique; Eyes small, terminal, eye-stalk slender; Epistome short but quite distinct; Chelipeds remarkably unequal in male, small and equal in female; Legs strong, dactyl very sharp; Abdomen consisting of 7 distinct segments in both sexes, often two or more segments fuse together.

5. *Uca dussumieri dussumieri* Maline Edwards, 1852

Two distinct long grooves running throughout the length in major dactyl of male on its outer surface and a similar groove on outer pollex; Inner dorsal margin of arm of major male chela adorned with an enlarged bicuspid distal tubercle; Merus of last pair of legs in males markedly slender than that of females; The space between two small antennules is very small.

6. *U. lactea annulipes* (Maline Edwards, 1837)

Carapace with antero-lateral margins almost straight, antero-lateral angles acute, dorso-lateral margins converging posteriorly and frontal groove broad; eye-brow short and narrow and orbit considerably oblique; tip of large dactylus hook-like; pollex tip with a small predistal tooth; gonopod without torson, anterior flange larger than posterior, gonopore opening through a narrow notch near posterior margin; The space in between two small antennules is more than *U. dussumieri.*

7. *U. triangularis bengali* Crane, 1975

Antero-lateral angles of carapace strongly acute; Dorso-lateral margins converging; Frontal groove moderately broad; Orbits strongly oblique; Eyebrow narrow; manus of large cheliped tuberculate; Dactylus with two broad shallow grooves-one just above gap and other in the usual proximal and subdorsal position; Chela tip simple, hooked and tip of dactylus hanging over tip of pollex; gonopod with short thumb.

8. *U. acuta acuta* (Stimpson, 1858)

Carapace strongly convex; Length of the carapace about three-fifth the greatest breadth; Front, measured between the eye-stalks, about a twelfth the greatest breadth of the carapace; Orbits moderately oblique, both upper and lower borders much sinuous; The fingers of the large male cheliped have tips that work as tongs, owing to the presence of an enlarged tooth near the tip: the meropodites of the last pair of legs are nearly foliaceous.

**Genus - *Dotilla* Stimpson,1858**

Lateral walls of carapace with deep convolute sculpture, front with narrow deflexed lobe; penultimate segment of 2$^{nd}$ maxilliped expanded; 4$^{th}$ segment of abdomen overlapping 5$^{th}$ and with a thick bush of hair at its distal end in both sexes; Abdomen of male not constricted; Chelipeds equal and dactylus slender and little deflexed.

9. *Dotilla blanfordi* Alcock,1900

Carapace with two lateral oblique grooves running from antero-lateral angle to postero-lateral angle; Six-rayed of equal shallow grooves running from the mesogastric towards front, hepatic, branchial and cardiac; Gastric region with 4 symmetrical tubercles; Dactylus in cheliped is a little longer than manus; merus of legs with tympana.

**Genus - *Dotillopsis* Kemp, 1919**

Carapace cuboidal and dorsal surface deeply grooved; Penultimate segment of 2$^{nd}$ maxilliped a little expanded and ultimate segment terminal in position; Tympana of merus ill-defined; 5$^{th}$, 6$^{th}$ and 7$^{th}$ abdominal segments of male narrow and 4$^{th}$ segment greatly expanded on either side; abdomen in female broadly oval.

10. *Dotillopsis brevitarsis* (de Man,1888)

Sculpture of carapace prominent with deeply grooved furrows; frontal groove continued to posterior margin, orbits shallow but distinct; Manus with conspicuous longitudinal carinae at lower and inner portion; Dactylus with a row of hair at upper margin; Merus of external maxillipeds larger than ischium; Tympana of merus ill-defined; 1$^{st}$ and 2$^{nd}$ walking legs at the lower portion of manus and carpus with tuft of hairs.

**Genus - *Macrophtalmus* Latreille,1829**

Carapace depressed and quadrilateral; Broader than long; Antero-lateral border with two prominent teeth; Frontal groove narrow; Orbit narrow occupying whole anterior border of carapace; Eyestalk very long and slender; Chelipeds equal or subequal in both sexes.

*11. Macrophthalmus pectinipes* Guerin,1839

Lateral border of carapace convergent posteriorly and carapace with large spinous tubercles; Frontal groove narrow; Orbits oblique, Upper orbital margin elegantly denticulated and lower orbital margin unevenly crenulated; Eyestalk slender and curved but not projected beyond antero-lateral angle; Antero-lateral border with 3 acute teeth while postero-lateral border covergent: Base of the dactylus of male cheliped with a tooth and the upper margin thickly hairy; Merus of walking legs with a spine.

**Genus - *Sesarma* Say,1817**

Carapace square or squarish, usually deep, often depressed, gastric region well outlined, usually divided into five subregions, the four antero-lateral subregions projecting as four prominent post-frontal lobes; Front broad, about half or more of the anterior border of carapace, deflexed obliquely or vertically; Lateral borders almost straight and parallel, with or without tooth behind the outer orbital angle, postero-lateral regions generally crossed by oblique parallel lines; Pterygostomial region and vertical walls of carapace reticulated with fine hairs; Basal antenna-joint broad; Flagellum slender, short, lying in the orbital hiatus; Antennules transverse, inter-antennular septum broad; Epistome well defined, distinct and rather short from front to back; Buccal cavity square cut; the external maxillipeds leaving between them a large rhomboidal gap, major part of this gap filled by fringe of hairs; Chelipeds massive and unequal in male, less so and subequal in female; Palm high, short; Fingers subacute, hollowed at tip; Legs differing little in length, third pair longest, first and fourth pairs shortest; merus thin, broad; Abdomen made up of 7 distinct segments in both sexes, occupying in the male the entire breadth of the last pair of legs; In female, last segment small and deeply embedded in sixth segment.

*12. Sesarma bidens* (De Haan,1835)

A small sharp tooth on the lateral border of the carapace immediately behind the outer orbital angle; carapace is slightly less transverse; the transverse ridges on the upper surface of the dactylus of the male chelae are coarser, tubercle-like and shorter.

*13. S. taeniolatum*, White,1847

Carapace deep, nearly flat dorsally, square, its sides nearly parallel; A transverse granular ridge on the inner surface of the palm; Finger meet at tip; Dactyl of the legs of good length.

*14. S. pictum* De Haan,1837

Carapace is not so broad, its length being about five-sixths of its breadth between the antero-lateral angles; The front is not so broad, its extent being only half the breadth of the carapace; The meropodites of the legs are not so broadly foliaceous, their greatest breadth, in the middle two pairs, being less than half their length.

*15. S. longipes* Krauss,1843

Length of the carapace is just equal to its breadth at the antero-lateral angles: Carapace deep; Its sides strongly divergent posteriorly where its breadth is much greater than its length; Two teeth (not including the orbital angle) on the lateral border, the posterior one being very small; Legs long and slender, with elongate dactyl; Third pair of legs not three times the length of the carapace.

**Genus - *Metaplax* H. Milne Edwards,1852**

Carapace quadrilateral, more or less flat, much broader than long; cephalothoracic regions are well outlined; Cervical and branchial grooves distinct; Front deflexed; Lateral borders of carapace straight or slightly curved anteriorly, almost parallel and divided into 4 or 5 teeth; Basal joint of antenna very short; Flagellum fairly long; Antenna lodged in the orbital hiatus; Antennules folded almost transversely, inter-antennular septum broad; Outer wall of orbit incomplete, lower border crenulate; Eyes not filling the orbits, eye-stalk not much extended; Epistome short, distinct and prominent, buccal cavity aquarish, a rhomboidal gap left between the external maxillipeds exposing the mandibles; Chelipeds differing markedly in the sexes; Legs slender; second and third pairs longer than the first and last pairs, third pair being the longest; Abdomen consisting of 7 distinct segments in both sexes; In males third to fifth segments often fused together; in females, seventh segment small and deeply impacted in the sixth.

*16. Metaplax crenulata* (Gerstaecker,1856)

Regional areas of carapace very distinct and strongly curved; No prominent lobe on the dentary edge of chelipeds; Legs spine.

16. *Metaplax distincta* H. Milne Edwards,1852

Lower orbital border of male extended to the level of second notch of the antero-lateral border of carapace and its orbital portion cut into 9-11 small, obscurely-bilobulate blunt teeth diminishing in size very regularly from within outwards; Anterior border of merus of last pair of leg armed with a subterminal spine.

17. *Metaplax intermedia* de Man, 1888

Dactylus of chelae of male with a prominent lobe projecting on the dentary edge: Chelipeds of male markedly unequal: Palm of larger cheliped of male higher than long.

**Genus - *Matuta* Weber,1795**

Carapace more or less flat, subcircular; Front almost as broad as orbit, trilobed, middle one more prominent than the others; Postero-lateral borders strongly convergent, generally with a strong spine at the junction of the antero-lateral and postero-lateral borders; Antenna extremely small, inconspicuous; Orbits large, oval with a deep groove in the lower border near the external orbital edge and a narrow gap at the inner angle; Eyestalks stout; External maxillipeds elongate, covering the buccal cavity; Chelipeds massive, equal; Stridulatory organ consisting of two elevated obliquely striated areas - one linear (proximal) and the other oval or subcircular (distal) on the inner surface of upper margin of palm of cheliped; Palm compressed, its upper border cristate and outer surface sculptured; Legs adapted for swimming and burrowing, dactylus of ambulatory legs broadened enormously in the first and last pair; Abdomen of adult male consisting of 5 segments with 3$^{rd}$-5$^{th}$ segments fused and of 7 separate segments in female and young males; first tergum in both sexes completely concealed under the carapace.

18. *Matuta lunaris* (Forskal,1775)

The tubercles on carapace rather indistinct, especially the anterior two; Front wider than orbit; Longitudinal ridge of dactylus strongly milled; A distinct spine-like tooth at the base of the lower outer angle of palm at its juncture with the wrist.

**Genus - *Doclea* Leach**

Body and appendages tomentose, usually very densely so; Carapace circular, armed at the sides and often on the dorsal surface also, with a few spines, the rostrum consists of 2 vertically compressed spines which are fused together in almost the whole of their extent and are usually short; The eyes are small and the commencing orbits are formed by an acute post-ocular tooth and a little-prominent supra-ocular eave; The antennae are very short and inconspicuous; The buccal frame is some what arched infront; The chelipeds are short and slender in the female; longer, stout, with an enlarged and inflated palm, in the adult male.

19. *Doclea japonica* Ortmann,1893

3 spines on the lateral border of the branchial region, the last being the largest and being placed rather higher up; there is a coarse spine or blunt tooth, on the posterior border of the carapace.

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*Uca acuta acuta* (male)

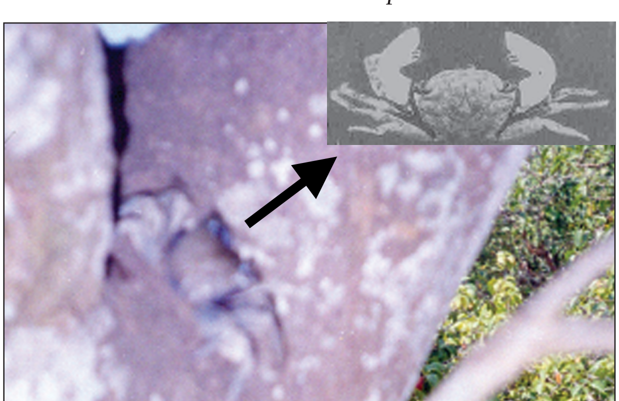

*U. acuta acuta* (female)


*Uca triangularis bengali* (male)


*Uca triangularis bengali* (female)


*Uca lactea annulipes*


*Macrophthalmus sp.*

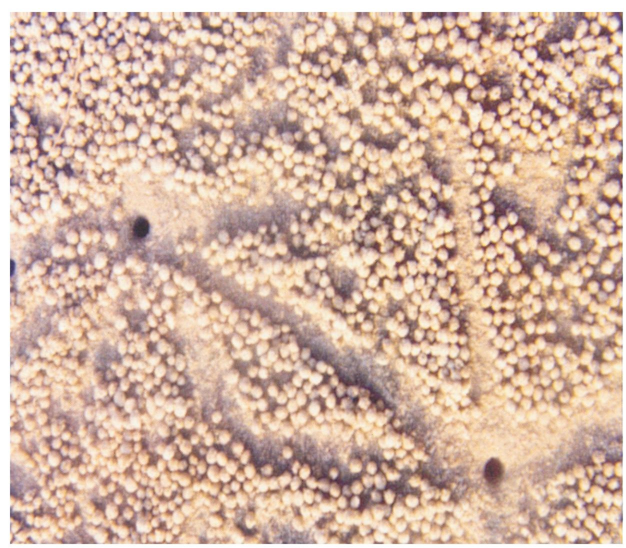

*Sesarma plicatum*


*Sesarma chiromantes bidens*

*Sesarma lanatum*

*Thalamita crenata*

*Scylla serrata*



*Bioturbation structure of the branchyuran crab Ocypoda macrocera*

# Molluscs

**Gurudas Chakravarty, Sunirmal Giri, S. K. Chakraborty, S. Dam Roy and Ansy Mathew**

Molluscs constitute a major group in the animal kingdom. In number of species, the mollusca is the second largest phylum after arthropoda. About 1,00,000 living species of molluscs are reported to be occuring in the world. They occupy almost all possible habitats - marine, brackish water, freshwater, land and also arboreal in some groups. India harbours an approximate total of 3,271 species of molluscs spread over nearly 591 genera and 220 families (Mitra and Dey, 1992). On the other hand, a checklist of molluscs of Indian estuaries includes a total of 245 species (120 gastropods and 125 bivalvs) [Subba Rao and Surya Rao ,1985]. They play a significant role in maintaining the steady state of the mangrove ecosystem and enhance its biological potentiality. Molluscs constitute an important faunal component in the food web of any estuarine-marine coastal environment. Previously several taxonomic and ecological survey of estuarine-marine molluscs of India was conducted by several workers (Banford,1867; Annandale and Kemp, 1916; Annandale and Prasad, 1919; Subba Rao *et al.*, 1983; Subba Rao *et al.*, 1992, Khalua *et al.*, 2003). The present study deals with the taxonomic survey (34 species, 24 genera, 22 families and 9 orders) of intertidal macrobenthic molluscs.

**Phylum - Mollusca**

Soft and unsegmented body in the adult stage; the visceral mass is enclosed by a thick muscular fold of the body wall, called *mantle;* a special structure named *radula* is present in most forms to assist in feeding; presence of ventral *mascular foot*.

**Class - Gastropoda**

Foot large and flat; well developed head with eyes and tentacles; radula present; torsion (coiling) of body mass at some time in development; shell present or absent, univalve and usually coiled.

**Class - Bivalvia**

Body enclosed in a bivalve shell and laterally compressed; head is indistinct; foot is tongue shaped; mouth is provided with two pairs of labial palps.

**Class - Cephalopoda**

Dorsoventrally elongated body; shell external or internal or absent; head distinct and large with well developed eyes, foot is modified as tentacles and siphon; Radula present.

**Order - Archaeogastropoda**

Presence of two bipectinate gills; two osphradia and single kidney; nervous system lacks pedal nerve cords.

**Order - Mesogastropoda**

Siphon, opercullum and penis are present; single auricle, single monopectinate gill, single osphradium and single kidney are present; nervous system lacks pedal nerve cords.

**Order - Neogastropoda**

Siphonal canal is much elongated; Radula is usually *rachiglossate* type [i.e. the teeth on the radular rows are bilaterally arranged with a median (*rachidian*) tooth and lateral and marginal teeth on two sides].

**Order - Basomatophora**

The eyes are located at the base of the non-retractile tentacles.

**Order - Soleolifera**

Slug-like shell-less bodies; single pulmonary sac; anus and female gonopore are situated at the posterior side while the male genital aperture is located at the anterior end.

**Order - Arcoida**

Well developed shell; straight hinge; adductor muscle scar small and sometime without myophoric ridge.

**Order - Pterioida**

Gills are splited; Interfilamentar and inter lamellar junctions are present and are nonvascular; a single large adducter muscle is present.

**Order - Veneroida**

Gill filaments fused; adductor muscles two and of equal size; gills serve to capture food.

**Order - Sepioida**

Internal shell present; ten oral arms with stalked suckers.

## Diagnostic characters of different families

## 1. Class - Gastropoda:

**Family - Naticidae**

Animal covered with spirally coiled univalve shell; shell globose, body whorle large, aperture moderate; spine reduced ; umbilicus present, completely filled by a callous, some times exposed as concentric depression; collumella not flattened.

**Family - Neritidae**

Univalve globose shell spirally coiled; umbilicus absent; columellar margins richly callous and flattened.

**Family - Trochidae**

Shell cone shaped, brightly coloured, internally nacreous; not attached with foreign bodies; umbilicus small or absent.

**Family - Littorinidae**

Shell not turreted but terminate, solid with horny epidermis; aperture subcircular; anterior canal absent; operculum present.

**Family - Assiminidae**

Shell not turreted, ovately conical, sub-globose with horny epidermis; aperture ovate.

**Family - Architectonidae**

Shell globose or elongated, cone shaped with flattened base whorls; aperture small oblique; umbilicus large, margin dentate.

**Family - Potamididae**

Shell elongate, without a distinct notch towards the posterior end; spire less than twice of the body whorl; columella twisted; Anterior canal present.

**Family -Epitoniidae**

Shell less elongate, turreted; body with definite, prominent sculpture; anterior canal absent.

**Family - Melongenidae**

Shell pear shaped, without continuous varices; upper part of body whorl smooth; anterior canal wide.

**Family - Nassariidae**

Shell pyriform; suture not deep; columella not twisted; sculpture with axial ribs; aperture wide.

**Family - Olividae**

Shell glossy and brightly coloured; aperture narrow elongated; operculum absent; spire elongate.

**Family - Ellobidae**

Shell less elongate, without operculum; anterior canal absent; columella with teeth.

**Family - Lymnaeidae**

Shell elongate, with a distinct spire and without operculum; columellar axis typically twisted.

**Family - Onchididae**

Shell absent; dorsal integument of the body very hard, surface beset with numerous hard protuberances giving tufted appearance; mantle with small eyes scattered on its surface.

## 2. Class - Bivalvia

**Family - Arcidae**

Shell well developed and encloses the entire animal; radiately striated or ribbed; hinge straight, scarcely arched; teeth arranged in straight line; ligamental pit absent; muscle scar without myophoric ridge or shelf.

**Family- Mytilidae**

Shell comparatively small (upto 60mm), mytiliform; ventral margin without any gap; ligament without nodules; anterior adductor muscle scar reduced or absent.

**Family - Ostreidae**

Shell strong, very thick; right valve without any foramen; ligament with modules; shell attached to substratum with one valve; anterior adductor muscle scar reduced or absent.

**Family - Solenidae**

Shell with one hinge teeth, straight, margins parallel; anterior adductor muscle scar well developed; hinge teeth also well developed and differentiated.

**Family - Donacidae**

Shell without posterior flexure; cardinal teeth two in either valve, tending to bifid; pallial line connected to adductor muscle; scar by distinct pallial sinus; radial striae present at least as marginal crenulations.

**Family - Gluconomidae**

Shell elongate, thin with periostracum; lateral teeth absent.

## 3. Class - Cephalopoda

**Family - Sepiidae**

Cephalopoda with eight arms; suckers sessile, no horny rings; tentacles retractile to pockets; internal shell calcified, body wide.

**Diagnostic characters of different species:**

*1.* *Nerita articulata* Gould, 1847

Shell semiglobular with numerous growth striae, semicircles and crossed by finer spiral lines; whorls one to one and half; spire represented by elevated portion of the body whorls, obliquely turned in words; aperture crescent shaped; columelar callous well developed.

2. *Neritina smithi* Wood,1828.

Shell oval, longer than broad, solid, white or dull brown with strong black, longitudinal, undulating and interrupted lines and bands, rarely with very fine, wavy and close set black lines, aperture broad, semilunar, columellar callous small and smooth; operculum semicircular; shell with distinct elevated spire.

3. *Neritina (Dostia)violacea* (Gmelin,1791).

Shell ovate with the spire quite hidden by the body whorl; dorsoventrally flattened; spire minute, periostracum yellowish-brown.

4. *Umbonium vestiarium* (Linnaeus, 1758).

Shell button-shaped, spire depressed, umbilicus closed, highly polished and brightly coloured with smooth shell.

4. *Littorina (Littorinopsis) melanostoma* Gray,1839.

Shell attenuated and conical, imperforate, yellowish white, punctate to elongate - rhomidal brown markings located between the spiral striae, sculptured with shallow incised spiral striae and fine oblique axial lines of growth.

5. *L. (Littorinopsis) scabra scabra* (Linnaeus, 1758).

Shell upto 43 mm in length, solid, with variable colour patterns, generally dark, violet grey to reddish brown, nodules white, columella reddish brown; sculptured with spiral cords and a row of small nodules on the penultimate whorl ; presence of spiral cords and axial growth lines; aperture with many fine lines and spotted with brown spots inside and outside.

6. *Littorina (Littoraria) undulata* Gray,1839.

Shell ornamented like marbled with brown spot; yellowish or cream in colour ; sculptured thickened.

7. *Assiminea brevicula* (Pfeiffer, 1854)

Shell globbose, with bright brick red or yellowish tan and with 6-7 whorls, sutures sharp, operculum conaus, thin and elongated.

8. *Assiminea francessiae* (Wood, 1828)

Shell thin, elongately ovate, spire elongate, body whorls with number of ridges and reddish bands running across and with 6-8 whorls, aperture sub-circular.

9. *Architectonica perspectiva* (Linnaeus,1755)

Shell thick, broad with flattened base and depressed conical spire; whorls inflated and perfectly straight; each whorl with distinct rib at the lower edge; bodywhorl sharply angular.

10. *Telescopium (Telescopium) telescopium* (Linnaeus,1758)

Shell broadly elongate; whorls sculptured with spiral ribs; body whorls without varix; columella twisted, trochoid shaped, elevated and conical; labial lip actualy curved.

11. *Cerithidea ( Cerithideopsis ) cingulata* ( Gmelin, 1791)

Shell narrowly elongate, spire on many whorles, whorles sculptured with both spiral and axial ribs. Body whorl with varix, collumella not twisted, aperture oblique and outer lip expanded broadly with distinct anterior canal.

12. *Cerithidea obtusa* (Lamarck,1822)

Robust shell, aperture broadly rounded with thick and flattened outer lip; sculpture with spiral threads crossed by prominent transpiral ridges

13. *Acrilla acuminata* (Sowerby,1844)

Shell elongate, trreted, spire with ten whorles; body whorl with prominent keel at base; sculptured with numerous spine vertical; aperture obliquely ovate.

14. *Natica tigrina* (Roeding,1798)

Shell globose, umbilicated, spire conically exerted, whorls rounded; columellar callous very thick especially at its base; aperture lunar-ovate ; colour white to cream, dotted all over with close - set purple-brown spots, dots generally arranged in a regular spiral line and occasionally they coalesce with these of adjacent lines.

15. *Natica vitellus* (Linnaeus,1758)

Globose, thick, excavated umbilicated with inflated body whorles; whorles rounded , spire low ; body whorl with pale broad light band in middle and whitish on the base and sutures.

16. *Pugilina cochlidium* (Linnaeus,1758)

Shell large and pear shaped; spire high and acute; whorls large and angulated; shoulder with tubercles; aperture ovately elongate; smooth columella, light brown in colour; shell covered with dark brown periostracum.

17. *Nassarius foveolatus* (Reeve , 1853)

Surface of the shells smooth, sculptured restricted to spiral whorles only, suture channeled, shell ovate, spire sharp, elongated and outerly varicose; colour of shell dull white with steel bluish tinge.

18. *N. stolatus* (Gmelin, 1790)

Shell ovately conical, acuminate, rather smooth, with chocolate or brown bands on the body; whorls convex, spire sharp, sculptured with slender axial ribs which become obsolete on the central area on the back of last whorl, interstices obscurely fine and cancellate; columella calloused, not expanded; outer lip thick and slightly varicose.

19. *Amalda ampla* (Gmelin,1791)

Shell elongate, slender, smooth and polished, shells whitish or rusty brown, spire elevated.

20. *Anadara granosa* (Linnaeus,1758)

Equivalve shell, orbicularly ovate, sculptured radiately ribbed, tuberculately crenulated.

21. *Ellobium (Auricula) gangeticum* Pfeiffer, 1855

Shell fusiformly ovate, curved with straw coloured epidermis; spire short; whorls tumid; aperture slightly expanded below; columella with two plates, peristome straight.

22. *Lymnaea (Pseudosuccinea) luteola* f. *typica* (Lamarck,1822)

Shell less inflated, thin and glossy, relatively smaller and laterally compressed; spire gradually tapering and aperture narrow.

23. *Onchidium tenerum* Stoliczka, 1869

Body oval, more or less elongated at the time of movement, soft, pulpy; mantle greenish-grey and with dark granular spots; eyes black and centrally situated in transverse fold; eye pedicles stout at the base with distinct swollen, granular tips; pulmonary orifice is situated at the posterior end of the mantle.

24. *O. tigrinum* Stoliczka, 1869.

Body large, ovate with strong coriaceous, hard mantle; upper surface with small granules enclosed between large tubercles; each with a jet black dot at the tip; pale greenish with blackish irregular spots; foot broad and extended upto the mantle; head and pedicles dark green; the pedicle thick at the base, thin in the middle, and slightly thickened tip which bear black eyes at upper surface.

25. *Modiolus striatulus* ( Hanley,1844)

Shell deep colour; ventral margin more depressed in the middle, sculptured with radiating ridges prominent and present on half of the body.

26. *Modiolus undulatus* (Dunker, 1856)

Shell gibbous, oblong, thin, rather inequivalve; umbo not so prominent, anteriorly situated; Yellowish brown.

27. *Crassostrea gryphoides* (Schlotheim, 1813)

Shell stout, bulky, elongated and irregular shape;

Inner margin pearly white; cavity beneath the hinge well marked; muscle scar broad and more or less oblong striations on the muscle scar.

28. *Crassostrea madra sensis*(preston 1916)

Shell straight, shape irregular, covered by numerous foliaecous laminae, left valve deep, right slightly concare, hinge narrow and elongated, adductor scar sub-central, reniform and dark purple in colour. A brackish water oyster. Shape varies with nature of substratum, flat rocky surface - shape round, soft mud - long and narrow uneven surfaces - shapes confirm to that of the substratum.

29. *Saccostrea cucullata* (Born,1778)

Shell with unequal valves, trigonal, some times oblong, extremely hard left valve thicker and larger than the right valve, outer margin with a number of folds which interlock with each other. Shell usually gray-white in colour with purple tinge towards the margin.

30. *Solen brevis* Gray, 1842

Shell almost straight with flattened tapering posterior end; posterior margin narrow; anterior margin broad abruptly truncated; sculpture with prominent growth lines.

31. *Donax (Latona) incarnatus* Gmelin,1791.

Shell compressed, triangular, variously coloured, posterior margin short and serrated, anterior margin rounded, ventral margin convex.

32. *Meretrix meretrix* (Linnaeus,1758)

Shell ventricose, highly variable in shape and colour, hinge narrow, posterior lateral tooth finely straited, anterior cardinal on left valve.

33. *Gluconome sculpta* (Sowerby,1828)

Shell elongately-oblong, anterior end short and angularly attanuated posterior end; sculptured with fine concentric striae and growth lines but eroded at the umbonal region; colour of the shell ranges from light greenish straw to white.

34. *Sepia aculeata* d'Orbigny, 1848

Tentacular suckers small, subequal and arranged in 12 longitudinal rows; proximal end of left ventral arm is hectocotylised with 3 rows of normal suckers and 5-6 rows of minute suckers.

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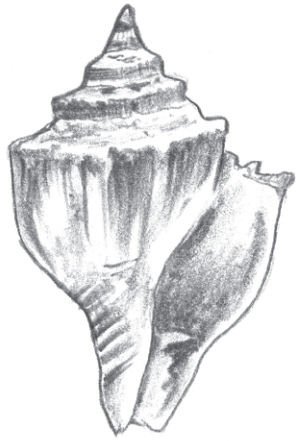
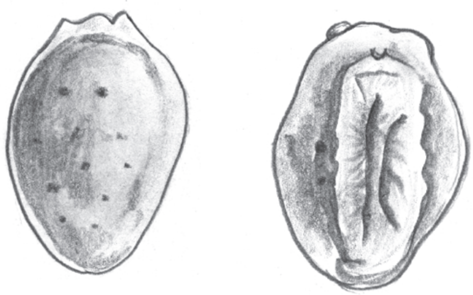


*Pugilina cochlidium*

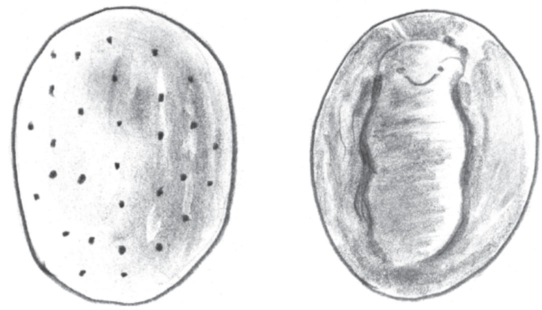
*Nassarius foveolatus*

*Amalda ampla*



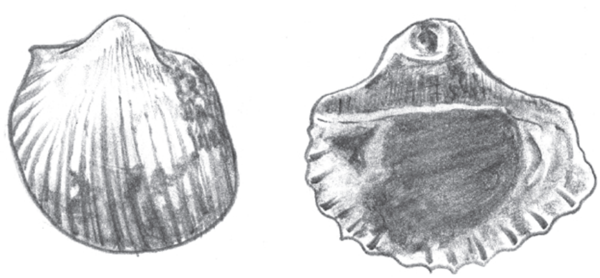
*Dorsal view* *Ventral view*

*Onchidium tenerum*



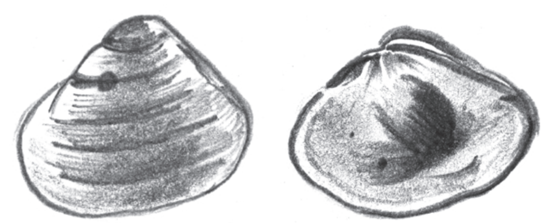
*Dorsal view* *Ventral view*

*Onchidium tigrinum*



*Dorsal view* *Ventral view*

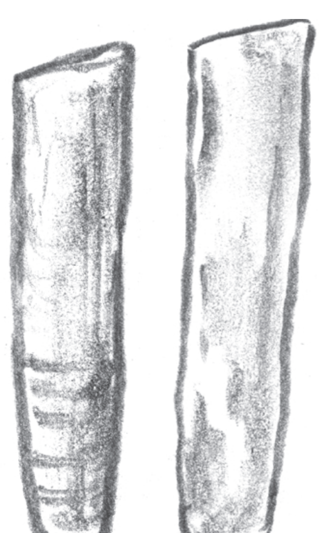
*Anadara granosa*



*Dorsal view* *Ventral view*

*Meretrix meretrix*

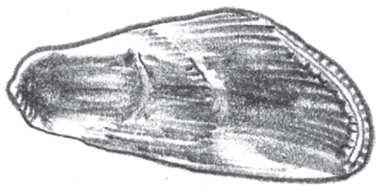
*Crassostrea gryphoides*



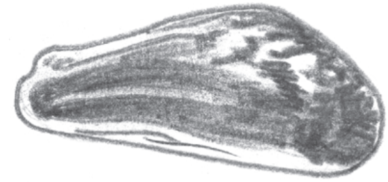
*Solen brevis*

*Saccostrea cucullata*

**Pencil drawing**

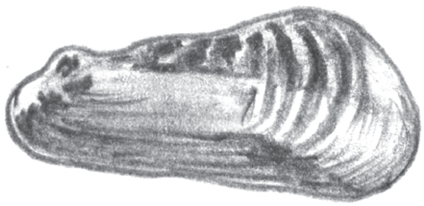


*Dorsal view*



*Ventral view*

*Modilus striatulus*



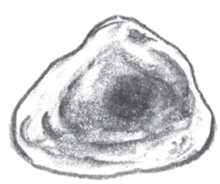
*Dorsal view*

*Ventral view*

*Modilus undulatus*

**Pencil drawing**

*Dorsal view*



*Ventral view*

*Donax incernatus*

*Sepia sp*

*Littorina scabra scabra*

*Assiminea brevicula*

*Assiminea francessiae*

*Architectonica perspectiva*

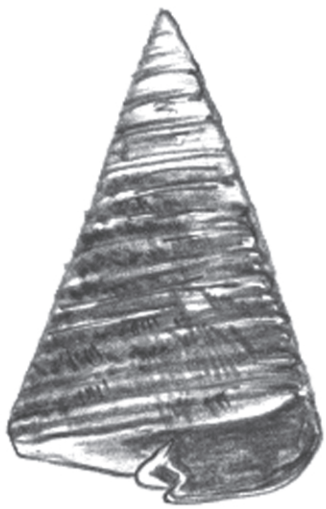
*Ellobium gangeticum*

**Pencil drawing**

*Dorsal view*

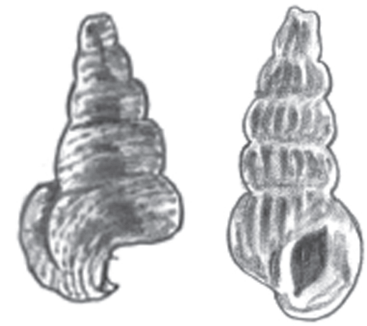
*Ventral view*

*Natica tigrina*



*Telescopium telescopium*

*Cerithidia cingulata*



*Dorsal view* *Ventral view*

*Cerithidia obtusa*

*Natica vitellus*

*Acrilla acuminata*

*Dorsal view* *Ventral view*

*Nerita articulata*

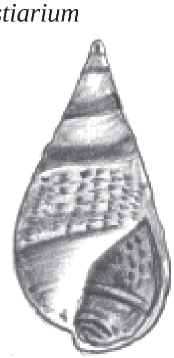
**Pencil drawing**

*Dorsal view* *Lateral view* *Ventral view*

*Umbonium vestiarium*

*Neritina smithi*

*Neritina violacea*

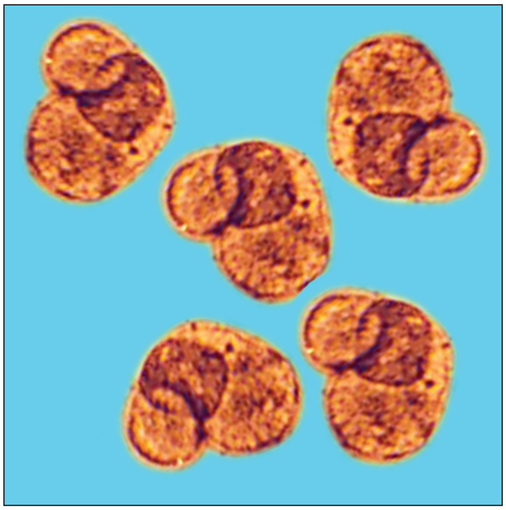


*Littorina melanostoma*

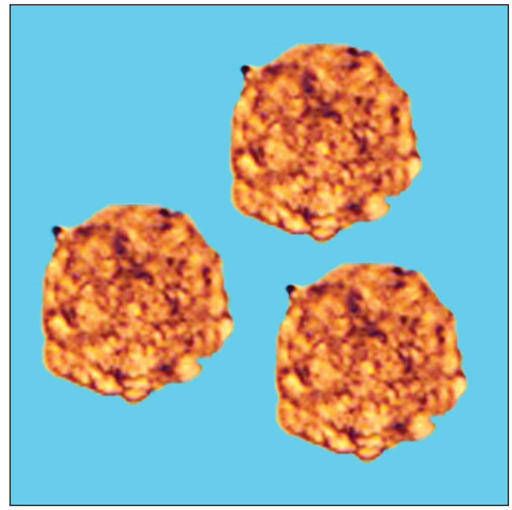
*Littorina undulata*

# Larvae of Mollusca

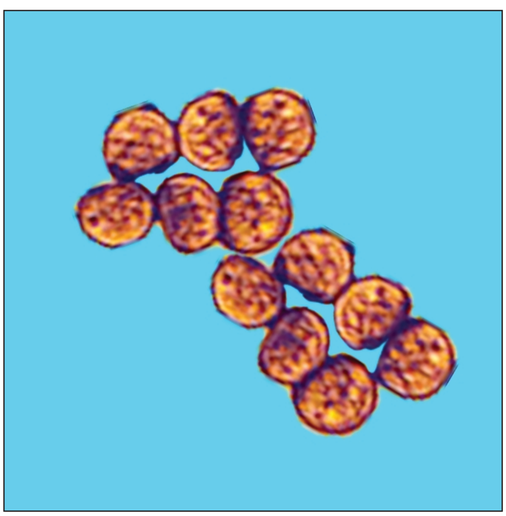
***(Prograssive stages of development)***



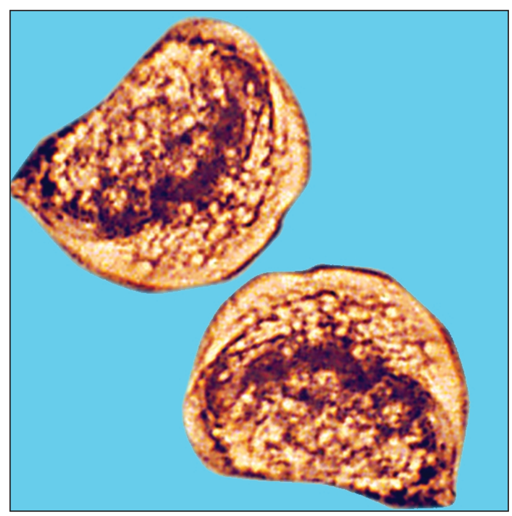
*Trefoil (4 celld) stage*



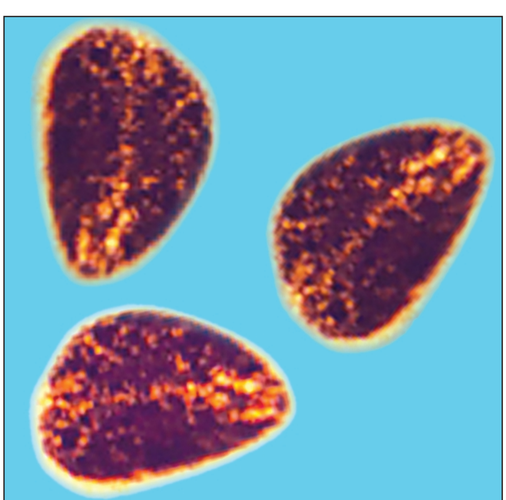
*Morula stage*



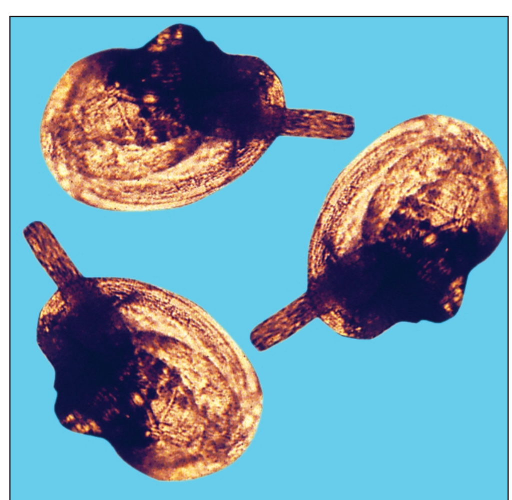
*Early D-shaped larvae*



*D-shaped advanced larvae*



*Early pediveliger stage*



*Pediveliger stage*

*Crassostrea madrasensis* (Indian Backwater Oyster)

*Saccostrea cucullata* (Indian Rock Oyster)

# Reptiles

**S. K. Chakraborty, Sunirmal Giri, Gurudas Chakravarty and George J. P.**

**Reptiles of Mangrove Ecosystems.**

| Species | Common name |
|---|---|
| **Class - Reptilia**<br>**Sub-class - Lepidosauria**<br>**Order- Squamata**<br>**Family- Varanidae** | |
| *Varanus bengalensis* (Daudin) | Indian Monitor |
| *V. salvator* (Laurenti) | Indian Water monitor |
| **Family - Colubridae** | |
| *Naja naja.* | Cobra |
| **Family - Viperidae** | |
| *Vipera russelli* | Chandrabora, russels viper |
| **Sub-class - Archosauria.**<br>**Order - Crocodylia**<br>**Family - Crocodylidae** | |
| *Crocodylus porosus* (Schneider) | Estuarine or salt water crocodile |
| **Sub-class - Anapsida**<br>**Order - Testudines**<br>**Family - Cheloniidae.** | |
| *Lepidochelys olivacea* (Eschscholtz) | Olive Ridley turtle |
| **Family - Emydidae.** | |
| *Batagur baska* (Gray) | River terrapin |
| *Geoclemys hamiltonii* (Gray) | Spotted pond turtle |
| **Family - Trionychidae.** | |
| *Lissemys punctata andersoni* (Bonnaterre) | Indian flapshell turtle |
| *Trionyx gangeticus* Cuvier | Ganges turtle |

### Class - Reptilia

1. Body covered with dry epidermal scales or scutes.
2. Pentadactyl clawed limbs (except snakes, where limbs are absent)
3. Typical cloaca present; cloacal aperture generally transverse.
4. Usually a post anal tail present.
5. Poikilothermic.

### Sub-class - Lepidosauria

1. Skull with two temporal vacuities.

### Sub-class - Archosauria

1. Skull with closed upper temporal vacuity.
2. Teeth thecodont.

### Sub-class - Anapsida

1. Roof of the skull is solid, no temporal vacuity.

2. Body is enclosed within a box made of dorsal carapace and ventral plastron.

**Order - Squamata**

1. Body covered with horny granular scales.
2. Supra temporal vacuity single or absent.

**Order - Crocodilia**

1. Body is covered with an exoskeleton of horny thick epidermal scales.
2. Epidermal scales modified into scutes.
3. Long tail, laterally compressed.
4. Longitudinal cloacal opening.
5. Male with a single penis.

**Order - Testudines**

1. In aquatic forms limbs for walking are modified into paddles for swimming.
2. Jaws with horny sheath or without teeth.
3. Tail is always present
4. Cloacal opening longitudinal.

**Diagnostic features of different species**

*1. Varanus bengalensis* (Daudin, 1758)

[Indian Monitor]

Snout convex at the end, its length from two and a half times its height; nostril an oblique slit nearer to the orbit than to end of snout; scales on crown of head is larger than the nuchal scales; supraocular scales small, subequal; digits elongated, tail strongly compressed with low double-toothed crest above; adult olive grey, or brownish above with sparse black spots, yellowish below, uniform or flecked with black.

*2. Varanus salvator* (Laurenti, 1768)

[Indian Water Monitor]

Snout depressed at the end, its length at least three times more than its height; nostril round or oval; nuchal scales smaller than those on crown of head; median supraoculars transversely enlarged; dorsal scales keeled; digits elongated; tail strongly compressed with a low double toothed crest above; a fully grown lizard dark olive, indistinctly spotted with yellow; the young blackish with small yellow and large rounded spots arranged in transverse rows.

*3. Naja naja.*

[Cobra]

Body with oblique scales without pit and no limbs or limb girdles; neck with cervical ribs and dilated to form a hood; the upper surface of the hood bears a binocellate mark forming a spectacle; fangs are followed by 1-3 teeth; small eyes with round pupils and with immovable eye lids; Tympanum absent; sharp constriction below hood and head.

*4. Vipera russelli.*

[Chandrabora; russels viper]

Head large, triangular, flat and covered with small scales; V - marks is placed overhead; body elongated and cylindrical; no limbs; body is covered with keeled scales; large black patches are arranged on the back; paired erectile fangs in front of the upper jaw, one on each maxillary bone and folded backward when not in use; 4$^{th}$ supra labial is the largest and it does not reach the eye; eyes have white margins and elliptical pupil.

*5. Crocodylus porosus* Schneider,1801.

[Estuarine or salt water crocodile]

17-19 upper teeth on each side, four in each premaxillary in the adult; snout 1.7-2.2 times as long as broad at the base; four large nuchals forming a square, with a smaller one on each side; dorsal armour of 6-8 longitudinal series of scutes; a strong ridge in front of eye, nearly half the length of the snout; no enlarged post-occipital scales; colour dark olive or brownish above, interspersed with yellow which is distinctive of this species.

*6. Lepidochelys olivacea* (Eschscholtz, 1829)

[Olive Ridley Turtle]

Carpace with 6 or more scutes; bridge with 4 inframarginals; each inframarginal is provided with pores on the hinder margin; single claw present on each flipper; dorsal colour grey to olive-green.

*7. Geoclemys hamiltonii* (Gray,1831)

[Spotted pond turtle]

The head large, broad snout rounded, as long as the orbit and slightly projecting beyond the lower jaw; skin of the posterior portion of head is divided into large shields; carapace with three well-defined keels; Plastron nearly as long as carapace, deeply notched at the back; colour jet-black above, spotted and streaked with yellow.

8. *Batagur baska* (Gray,1831)

[River Terrapin]

The head comparatively small with an upturned, pointed and strongly projecting snout; skin of the posterior part of head divided into small shields; carapace smooth, shining, sub-truncated anteriorly, rounded posteriorly, heavy and moderately depressed; distinguished from other terrapins by the presence of only four, instead of five claws on the forelimb.

9. *Lissemys punctata andersoni* (Bonnaterre, 1789)

[Indian Flapshell turtle]

Distinguished from all other freshwater species of Indian turtles by the presence of skin flaps on the Plastron for hiding hindlimbs and tail; shell low domed, oval in adults, almost circular in the young; shell bones finely granular, eight pairs of coastal plates, the last pair meeting medially; Head oval terminating in tubular nostrils; digits fully webbed. Carapace olive-brown; Plastron yellowish or white.

10. *Trionyx gangeticus* Cuvier,1824.

Carapace is covered by greenish soft skin with yellowish spots; snout elongated into a proboscis; digits are distinct, united by webs; 3 clawed digits are present in each limb; eyes are on the top of the head.

*Crocodylus porosus*

# Mammals

S. K. Chakraborty, Sunirmal Giri, Gurudas Chakravarty and S. Dam Roy

## Mammals of Mangrove Ecosystems

| Species | Common Name |
|---|---|
| **Class - Mammalia**<br>**Sub-Class - Theria**<br>**Infra-Class - Eutheria**<br>**Order - Insectivora**<br>**Family - Soricidae** | |
| *Suncus murinus* (Shaw) | House Shrew |
| *Pteropus giganteus giganteus* (Brunnich) | Indian Flying Fox |
| *Cynopterus sphinx sphinx* (Vahl) | Short-nosed Fruit Bat |
| *Taphozous longimanus longimanus* Hardwicke | Long-armed Sheath-tailed Bat |
| *Megaderma lyra lyra* Geoffroy | Indian False Vampire |
| *Rhinolophus lepidus lepidus* Blyth | Little Indian Horse-shoe Bat |
| *Pipistrellus mimus* Wroughton | Indian Pygmy Pipistrelle |
| *Scotophilus kuhli kuhli* Leach | Lesser Yellow Bat |
| *Macaca mulatta mulatta* (Zimmermann) | Rhesus Macaque |
| *Presbytis entellus entellus* (Dufresne) | Hanuman Langur |
| *Manis crassicaudata* Gray | Indian Pangolin |
| *Canis aureus indicus* Hodgson | Asiatic Jackal |
| *Vulpes bengalensis* (Shaw) | Bengal fox |
| *Vivera zibetha zibetha* Linnaeus | Large Indian Civet |
| *Viverricula indica indica* (Desmarest) | Small Indian Civet |
| *Herpestes auropunctatus auropunctatus* (Hodgson) | Small Indian Mangoose |
| *Herpestes palustris* Ghose | Marsh Mangoose |
| *Felis chaus kutas* Hodgson | Jungle cat |
| *Felis bengalensis bengalensis* Kerr | Leopard Cat |
| *Felis viverrina* Bennett | Fishing cat |
| *Panthera tigris tigris* (Linnaeus) | Tiger |
| *Sus scrofa cristatus* Wagner | Indian Wild Boar |
| *Axis axis axis* (Erxleben) | Spotted Deer |
| *Funambulus pennanti* Wroughton | Northern Palm Squirrel |
| *Hystrix indica indica* Kerr | Indian Crested Porcupine |
| *Rattus rattus arboreus* (Horsfield) | House Rat |
| *Mus musculus urbanus* Hodgson | House Mouse |
| *Mus booduga booduga* (Gray) | Little Indian Field Mouse |
| *Bandicota bengalensis bengalensis* Gray | Lesser Bandicoot-Rat |
| *Platanista gangetica* (Roxburgh) | Gangetic Dolphin |

**Diagnostic characters of different species:**

1. *Suncus murinus caerulescens* (Shaw)

   [Common name - House Shrew]

   Largest of the Indian house shrews; fur short, less than 5mm in length; tail thick on base and thinly clad with hairs.

2. *Pteropus giganteus giganteus* (Brunnich)

   [Common name - Indian Flying Fox]

   Large bat rufous-brown around head and neck; a conspicuous orange or honey-coloured band across upper back; lower back blackish brown; ventral parts dark chestnut brown; naked skin of wings, uropatagium, ears and muzzle jet black; no external tail; a narrow flap of skin inside each leg.

3. *Cynopterus sphinx sphinx* (Vahl)

   [Common name - Short-nosed Fruit Bat]

   Medium-sized (forearm around 70.0mm) fruit bat with white margin to ears; metacarpals and phalanges whitish; nostrils divergent with deep inter-nasal groove; dorsal colour grey or greyish-brown, paler ventrally (often with a broad rufescent or chestnut area around the shoulders and throat); naked skin of wings, muzzle, etc., blackish brown; tail reduced and rod-like.

4. *Taphozous longimanus longimanus* Hardwicke

   [Common name - Long-armed Sheath-tailed Bat]

   A dark brown (adult males usually lighter brown), medium-sized bat with broad tragus; gular sac moderately developed in males and in females represented by a rudimentary fold of naked skin; radio-metacarpal pouch moderately developed; inner margin of ear smooth (not papillate); lower lip scarcely grooved.

5. *Megaderma lyra lyra* Geoffroy

   [Common name - Indian False Vampire]

   Medium sized bat (but larger than *M. spasma spasma*); forearm (60-70mm); posterior termination of nose-leaf truncated; dorsal colour slaty grey.

6. *Rhinolophus lepidus lepidus* Blyth

   [ common name - Little Indian Horse-shoe Bat]

   Small, (forearm around 40.0 mm on average); connecting process higher than top of sella forming a deep notch between them; skull broader zygomatic width more than 8mm, maxillary tooth-row longer, more than 6mm.

7. *Pipistrellus mimus* Wroughton

   [Common name - Indian Pygmy Pipistrelle]

   Smallest (forearm 25.0-32.0mm) Fur dense and short; dorsal coloration bistre brown, base of hairs almost black; ventral parts lighter; face, ears and wing-membranes almost black; ears small and scarcely triangular; tragus short and curved forward; post-calcarial lobe present; wings from base of toes.

8. *Scotophilus kuhli kuhli* Leach

   [Common name- Lesser Yellow Bat]

   Ears small, round at tips; tragus semilunar, markedly convex on posterior border, concave anteriorly, tip slender and forward pointing; wing from side of foot near base of toe; tip of tail free; fur short, dense and sleek; dorsal colour olive-brown, ventral colour creamy white with a tinge of red.

9. *Macaca mulatta mulatta* (Zimmermann)

   [Common name - Rhesus Macaque]

   Medium-sized, with a rather short tail (about half of the head and body length); crown hairs grow back from brows; face light pink; upper back olive in colour; loins, rump and base of tail of orange red hue.

10. *Presbytis entellus entellus* (Dufresne)

   [Common name - Hanuman Langur]

   A large black faced, grey bodied langur with long limbs, tail longer than head and body; whiskers short, only partly covering the ears; crown of head a little paler than the nape and shoulders; crown hairs radiate from a frontal whorl; hands and feet black or brown and strongly contrasted with that of arms and legs.

11. *Manis crassicaudata* Gray

   [Common name - Indian Pangolin]

   Body covered with 11-13 longitudinal rows of overlapping horny scales; tip of tail without any naked glandular area.

12 *Canis aureus indicus* Hodgson

   [Common name - Asiatic Jackal]

   Smaller than wolf, and lacks the arching brows and elevated forehead; dorsal colour typically a mixture of black and white, washed with buff about the shoulders, ears and legs.

13. *Vulpes bengalensis* (Shaw)

[Common name - Bengal fox]

A grey-coloured fox, having slender limbs, back of ears sandy brown and tail-tip black.

14. *Vivera zibetha zibetha* Linnaeus

[Common name - Large Indian Civet]

Body markings indistinct and cloudy; tail with complete dark and light rings; crest of long, black, erectile hairs present on the back; anterior upper molars distinctly triangular.

15. *Viverricula indica indica* (Desmarest)

[Common name - Small Indian Civet]

Body pattern consists of small spots on the fore-quarters, larger spots tending to run into longitudinal lines on the flanks and form six to eight strips down the back; muzzle short and weak; no dorsal crest of long hairs on the back; claws unprotected by sheaths of skin.

16. *Herpestes auropunctatus auropunctatus* (Hodgson)

[Common name - Small Indian Mangoose]

Contour hairs short, soft, with a few bands; legs not darker than body; muzzle dark brown; cranium gradually narrows from the orbit.

17. *Herpestes palustris* Ghose

[Common name - Marsh Mangoose]

Muzzle black; cranium narrows abruptly behind the orbit so that postorbital region appears as a constriction between frontals and cranium.

18. *Felis chaus kutas* Hodgson

[Common name - Jungle cat]

Medium-sized, head and body 64-72 cm in length; tail terminating in a black tip; pelage unspotted except on lower flanks and elbow; black horizontal strips on the innerside of forelegs; back of ears reddish chestnut with inconspicuous hair tuft.

19. *Felis bengalensis bengalensis* Kerr

[Common name - Leopard Cat]

A small-sized cat, head and body length 61-66 cm; back of ears black, with round whitish spot in the centre; pelage ornamented throughout with blackish brown spots; four longitudinal black bands commence on the forehead, continue over the head to the neck, then break up into short bands or elongated sets on the shoulders.

20. *Felis viverrina* Bennett

[Common name - Fishing cat]

A medium-sized cat, head and body length 66-70 cm; back of ears black, with round whitish spot in the centre; body covered with black or brown spots throughtout, spots always longer than broad; six to eight black lines run from the forehead to the nape, breaking up into shorter lines and spots on the shoulders; several cross bands present on the forehead and throat.

21. *Panthera tigris tigris* (Linnaeus)

[Common name - Tiger]

Ground colour body orange-Tawny, with vertical black stripes.

22. *Sus scrofa cristatus* Wagner

[Common name - Indian Wild Boar]

Large, height at shoulders 76-102 cm; a crest of black bristles present from nape to the back; tail long, extending nearly to hocks.

23. *Axis axis axis* (Erxleben)

[Common name - Spotted Deer]

Coat bright rufous-fawn, profusely spotted with white, at all ages and seasons; Antlers with three tines, a long brow-tine set nearly at right angles to the beam; latter divides into two branches.

24. *Funambulus pennanti* Wroughton

[Common name - Northern Palm Squirrel, Five-striped Squirrel]

Dorsal surface of body having 5 buff stripes.

25. *Hystrix indica indica* Kerr

[Common name - Indian Crested Porcupine]

A crest of bristles, 15-30 cm long, present on the crown; quills bear several alternating bands of white and blackish brown.

26. *Rattus rattus arboreus* (Horsfield)

[Common name - House Rat]

Under parts of body white or dirty white; maxillary tooth row less than 6.6mm in length or more than 16% of occipitonasal length.

27. *Mus musculus urbanus* Hodgson

[Common name - House Mouse]

Anterior palatal foramina long, more than one-fifth of occipitonasal length, and extending posteriorly between maxillary tooth rows.

28. *Mus booduga booduga* (Gray)

[Common name - Little Indian Field Mouse]

Body fur soft; smaller in size, occipitonasal length less than 20mm; Ventral surface of body white in colour.

29. *Bandicota bengalensis bengalensis* Gray

[Common name - Lesser Bandicoot-Rat]

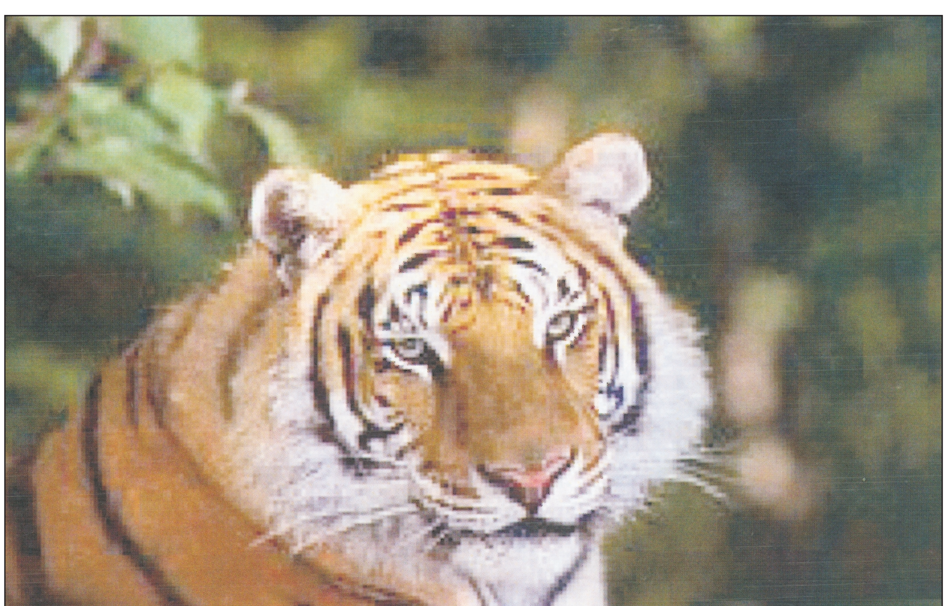
Size small, head and body length less than 220 mm, anterior palatal foramina narrower posteriorly; nasals short, less than one-third occipitonasal length.

30. *Platanista gangetica* (Roxburgh)

[Common name - Gangetic Dolphin]

Body-size 214-244 cm, but sometimes a little longer; females larger than males. Colour of body blackish throughout; Dorsal fin rudimentary.

*Axis axis*



*Panthera tigris tigris*

# Avian Fauna

**S. K. Chakraborty, Sunirmal Giri,Gurudas Chakravarty, S. Dam Roy and A. K. Sadhu**

The mangroves together with the extensive areas of mudflats and sandflats provide a wide range of niches for avian species. Different workers like - Osmaston (1904), Roonwal (1939), Saha *et al*, (1971) and Majumder *et al*. (1992) have contributed to the knowledge of Ornithology of Mangrove Ecosystem which is attracted by large number of birds both in reclaimed areas and in the mangrove forest. More than 300 species have been recorded earlier from mangroves area in which a number of them are migratory (Choudhury and Choudhury, 1994)

**A list of Birds recorded from Mangrove Ecosystems.**

| Species | Common name |
|---|---|
| **Class - Aves**<br>**Sub-Class - Neornithes**<br>**Super-Order - Neognathae**<br>**Order - Pelecaniformes**<br>**Family - Phalacrocoracidae** | |
| *Phalacrocorax niger* (Vieillot) | Little Cormorant |
| *Phalacrocorax carbo* (Linnaeus) | Large Cormorant |
| **Order - Ciconiiformes** | |
| **Family - Ardeidae** | |
| *Ardea cinerea* Linnaeus | Grey Heron |
| *A. purpurea manilensis* Meyen | Eastern Purple Heron |
| *Bubulcus ibis coromandus* (Boddaert) | Cattle Egret |
| *Egretta intermedia intermedia* (Wagler) | Smaller or Median Egret |
| *E. garzetta garzetta* (Linnaeus) | Little Egret |
| *Nycticorax nycticocorax nycticocorax* (Linnaeus) | Night Heron |
| **Family - Ciconiidae** | |
| *Anastomus oscitans* (Boddaert) | Openbill Stork |
| **Family - Threskiornithidae** | |
| *Threskiornis aethiopica melanocephala* (Latham) | White Ibis |
| **Order - Anseriformes** | |
| **Family - Anatidae** | |
| *Dendrocygna javanica* (Horsfield) | Lesser Whistling Teal |
| **Order - Falconiformes** | |

| Species | Common name |
|---|---|
| **Family - Accipitridae** | |
| *Haliastur indus indus* (Boddaert) | Brahminy Kite |
| *Milvus migrans govinda* (Sykes) | Pariah Kite |
| *Haliaeetus leucoryphus* (Pallas) | Ringtailed or Pallas's Fishing Eagle |
| **Order - Galliformes** | |
| **Family - Phasianidae** | |
| *Gallus gallus murghi* Robinson & Kloss | Indian Red Jungle Fowl |
| **Order - Gruiformes** | |
| **Family - Rallidae** | |
| *Amaurornis phoenicurus chinensis* (Boddaert) | Chinese Whitebreasted Waterhen |
| **Order - Charadriiformes** | |
| **Family - Charadriidae** | |
| *Vanellus indicus indicus* (Boddaert) | Redwattled Lapwing |
| *Pluvialis dominica fulva* (Gmelin) | Eastern Golden Plover |
| *Gallinago gallinago gallinago* (Linnaeus) | Fantail Snipe |
| *Calidris minuta* (Leisler) | Little Stint |
| **Order - Apodiformes** | |
| **Family - Apodidae** | |
| *Apus affinis affinis* (J.E.Gray) | Indian House Swift |
| *Cypsiurus parvus batasiensis* (J.E.Gray) | Indian Palm Swift |
| **Order - Coraciiformes** | |
| **Family - Alcedinidae** | |
| *Ceryle rudis leucomelanura* Reichenbach | Indian Pied Kingfisher |
| *Alcedo atthis bengalensis* Gmelin | Indian Small Blue Kingfisher |
| **Family - Meropidae** | |
| *Merops orientalis orientalis* Latham | Indian Small Green Bee-eater |
| **Order - Piciformes** | |
| **Family - Picidae** | |
| *Dinopium benghalense benghalense* (Linnaeus) | Northern Goldenbacked Woodpecker |
| **Order - Passeriformes** | |
| **Family - Dicruridae** | |
| *Dicrurus adsimilis albirictus* (Hodgson) | North Indian Black Drongo |
| *D. caerulescens caerulescens* (Linnaeus) | Indian Whitebellied Drongo |
| **Family - Sturnidae** | |
| *Acridotheres fuscus fuscus* (Wagler) | Northern Jungle Myna |
| **Family - Muscicapidae** | |

| | |
|---|---|
| *Monticola cinclorhynchus* (Vigors) | Bullheaded Rock Thrush |
| *M. solitarius pandoo* (Sykes) | Indian Blue Rock Trush |
| **Family - Motacillidae** | |
| *Motacilla flava beema* (Sykes) | Blueheaded Yellow Wagtail |
| **Family - Nectariniidae** | |
| *Nectarinia asiatica asiatica* (Latham) | Indian Purple Sunbird |
| **Family - Ploceidae** | |
| *Ploceus philippinus philippinus* (Linnaeus) | Indian Baya |
| *Lonchura punctulata punctulata* (Linnaeus) | Indian Spotted Munia |

**Class - Aves.**

Body is covered by feathers; fore limbs are modified as wings and have powerful flight muscle; Body spindle shaped; bones are pneumatic; Air sac present; a sound producing organ, *syrinx* is present.

**Sub-class - Neornithes.**

Short tail with a terminal pygostyle and with semicircularly arranged feathers; teeth absent; usually the claws are not present in more than two digits; well developed sternum bears a distinct *keel* or *carina.*

**Super-order - Neognathae.**

The slender vomer separates the palatines imperfectly; the palatines are protruded posteriorly to be in contact with the base of the cranium and remain movably articulated with small pterygoids - this type of jaw arrangement is known as neognathous condition; they are able to fly; most of them posses *keel* or *carina.*

**Order - Pelecaniformes.**

All are aquatic and fish-eaters; long beaks have wide gap; size is usually large and body is adapted for diving; hind limb has four digits which are completely webbed; they make nests in a colony and feed the nestlings by regurgitated food.

**Order - Ciconiiformes.**

All the birds have long naked legs and long bills; the legs are adapted for walking on marshes and mudflats; four toes are present in each foot which only in one family (Phaenicopteridae) are webbed; the beak has sharp-cutting edges.

**Order - Anseriformes.**

Beak is provided with special tectile organ to help in selecting food; all the toes are webbed.

**Order - Falconiformes.**

Body is strongly built with prominent hook-like beak with cutting edge and the feet are provided with curved pointed claws in the digits; the lower beak remains enclosed by the upper beak, bears wart-like variedly coloured protruberance called *cere* which is pierced by nostrils; feathers are stiff and cover the legs except the digits; eyes are laterally placed.

**Order - Galliformes.**

Head small but body compact; the legs are massive, clawed and used for scratching the soil to search food; three toes are anteriorly directed and one is posteriorly directed; in most members, the wings are short and round; the beaks are strongly built and arches, most suitable for picking up grains and seeds; sexual dimorphism presents.

**Order - Gruiformes.**

Primarily aquatic but some have settled in grass-land and some have become reed dwellers; toes are not webbed; nests are built on the ground.

**Order - Charadriiformes.**

Live near water, some live on shore, some on aquatic leaves and some become aquatic; feet show various modifications according to habitats.

**Order - Apodiformes.**

These birds have short legs and long wings; they can fly very swiftly; and are usually insect feeders but humming birds take nectar in swifts; the mouth is broad and eyes are large; in humming birds, the tongue is protrusible and wings can perform hovering movement.

**Order - Coraciiformes.**

In most species, the wings and legs are short; the beak is long; body is brightly coloured and nests are built up as holes in the trees; in some forms a few anteriorly directed toes are fused (syndactylous) and in others one of the toes is reversed (zygodactylous).

**Order - Piciformes.**

The most important character is the occurance of zygodactylous feet, second and third toes are directed forward and the first and fourth are pointed backwards; usually insectivorus but some forms may be herbivorus; most members prepare nest in holes but one family (Indicatoridae) lays eggs in the nests of other birds.

**Order - Passeriformes.**

All are adapted to land life and in all, the four digit are present at the same level; nestlings are hatched only with a few feather tracts and are helpless at the beginning.

**Diagnostic characters of different species :-**

**Order - Phelecaniformes**

**Family - Phalacrocoracidae**

Genus - *Phalacrocorax* Brisson, 1760

Neck and body long, rather spindle-shaped, bill laterally compressed.

1. *Phalacrocorax niger* (Vieillot,1817)

   [Common name - Little cormorant]

   A glistening black duck-like bird; a short crest on occiput and neck; bill stouter; a small white patch on throat; forehead domed shaped, stiff long tail; sexes alike.

2. *Phalacrocorax carbo* (Linnaeus,1801)

   [Common name - Large cormorant]

   A black duck-like water bird with slender bill, hooked at tip; tail longish and stiff; facial skin and throat white; gular pouch bright yellow.

**Order - Ciconiiformes**

**Family - Ardeidae**

Genus - *Ardea* Linnaeus, 1758

Large sized, above 97 cm.

3. *Ardea cinerea* Linnaeus,1758

   [Grey Heron]

   Ashy-gray with white crown and neck with a long black occipital crest below a prominent black dotted line down middle of foreneck; leg and neck very long; breast with elongated black-streaked white feathers; abdominal feathers grayish white.

4. *A. purpurea manilensis* Meyen,1834

   [Common name - Eastern purple heron]

   Purplish blue or slaty bird with blackish wing and tail; crown and crest slaty black, rest of head and neck ferruginous with boldly striped-black; chin and throat white; upper breast buffy-white with black and chestnut streaks; abdomen slaty black and chestnut.

   Genus - *Bubulcus* Bonaparte, 1855

   Medium or small-sized, below 63 cm; plumage mainly white in colour; head and neck white throughout; bill yellow in colour.

5. *Bubulcus ibis coromandus* (Boddaert,1783)

   [Common name - Cattle egret] (Fig. 1)

   A snow white bird usually seen on or with grazing cattle; bill yellow; orbital and facial skin greenish yellow; legs and feet black; during breeding head, neck and back the golden buff feathers disintegrate and hair like.

   Genus - *Egretta* Forster,1817

   Medium or small-sized, below 63 cm; plumage mainly white in colour; head and neck white throughout; bill black in colour.

6. *Egretta intermedia intermedia* (Wagler,1829) (Fig. 2)

   [Common name - Smaller or median egret]

   Plumage entirely white; occipital crest absent; in breeding, on back as well as on breast presence of decomposed filamentous plumes; legs and feet black; bill black; yellow at base in breeding season.

7. *E. garzetta garzetta* (Linnaeus,1766)

   [Common name - Little egret]

   Size equal to hen. Plumage snow-white, bill black; legs black, feet orange yellow; in breeding season, nuchal crest of two long narrow plumes and filamentous feathers on back and breast.

   Genus-*Nycticorax* T. Forster,1817

   Medium or small-sized, below 63 cm; plumage genarally white and grey in colour.

8. *Nycticorax nycticocorax nycticocorax* (Linnaeus,1758)

   [Common name - Night heron]

   Size equal to Pond Heron; bill stout, back and scapular ashy-grey with greenish black; forehead and sides of head white; occipital crest, crown and nape black; sides of breast and belly ashy-grey; legs and feet dull green; young birds streaked brown; sex alike.

**Family - Ciconiidae**

Genus - *Anastomus* Bonnaterre,1791

Mandibles leaving open space near middle of bill.

*9.* *Anastomus oscitans* (Boddaert,1783)

[Common name - Openbill Stork]

Size equal to large duck; bill reddish black with arching mandibles leaving a narrow open gap between them is diagnostic; legs and feet pinkish brown; neck, back and breast white, mantle, wings and tail greenish black.

**Family - Threskiornithidae**

Genus - *Threskiornis* G.R.Gray,1842

Bill slender, slightly downcurved, neck bare; plumage usually white, nostril linear.

*10.* *Threskiornis aethiopica melanocephala* (Latham,1790)

[Common name - White Ibis]

A large white marsh bird; entire plumage except head and neck snow white, head and neck black; bill down curved, long and stout; in breeding season plumage some slaty gray on scapulars and in wings and ornamental plumes at base of neck.

**Order - Anseriformes**

**Family - Anatidae**

Genus - *Dendrocygna* Swainson,1837

Hind toe narrowly lobed; bill rather flat and broad; primaries equal to secondaries in length.

11. *Dendrocygna javanica* (Horsfield,1821)

[Common name - Lesser Whistling Teal or Tree Duck]

Small pale brown and maroon-chestnut coloured bird; upper tail-coverts uniformly chestnut; sexes alike; feeble, flapping, jacana-like flight accompanied by the constantly uttered shrill whistling.

**Order - Falconiformes**

**Family - Accipitridae**

Genus - *Haliastur* Selby,1840.

Head and neck feathered; upper mandible without teeth; lores unfeathered; tarsus short, less than two times length of bill from tip to gape; front of tarsus scutellate; tail not forked; fourth primary longest.

12. *Haliastur indus indus* (Boddaert,1783)

[Common name - Brahminy Kite]

Size slightly smaller; head, neck, upper back and breast white; lower back, wings, abdomen and tail rusty red or deep chestnut; tips of wings black; Immature birds chocolate - brown in colour.

Genus - *Haliaeetus* Savigny,1809

Head and neck feathered; upper mandible without teeth; lores unfeathered; tarsus short, less than two times length of bill from tip to gape; front of tarsus scutellate; tail not forked; third primary longest.

13. *Haliaeetus leucoryphus* (Pallas,1771)

[Common name - Ringtailed or Pallas's Fishing Eagle]

Size bigger than kite; back and wings dark brown, head, neck and upper back pale golden brown; tail white with terminal band, legs and feet dull white; females are larger than male.

Genus - *Milvus* Lacepede,1799.

Head and neck feathered; upper mandible without teeth; lores unfeathered; tarsus short, less than two times length of bill from tip to gape; front of tarsus scutellate; tail forked.

14. *Milvus migrans govinda* (Sykes,1832)

Head, back and tail dark fulvous-brown; bill black, legs and feet yellow, claws black; tail deeply forked.

**Order - Galliformes**

**Family - Phasianidae**

Genus - *Gallus* Brisson,1760

No ocellations on tail or tail coverts; wing over 200mm; a flesh erect comb on the crown.

15. *Gallus gallus murghi* Robinson & Kloss,1920

[Common name - Indian Red Jungle fow1] (Fig. 3)

Size equal to a domestic Fowl; hen differ from cock; in cock, back with orange red and yellow hackles on neck and rump; under parts uniformly black, wings with bright blue wing patches; in hen, back reddish brown finely vermiculated with buff and black; under parts light rufous brown.

**Order - Gruiformes**

**Family - Rallidae**

Genus - *Amaurornis*

Bill from gape much shorter than tarsus; frontal shield absent to slightly developed; quill three to six longest; first shorter than eight.

16. *Amaurornis phoenicurus chinensis* (Boddaert,1783)

[Common name - Chinese Whitebreasted waterhen] (Fig. 4)

Crown, hind neck, wings, back and stuby tail dark slaty grey; forehead, sides of head, chin, throat, breast and belly pure white; vent and under tail coverts rufous; legs and feet yellowish green; the base of upper mandible red.

**Order - Charadriiformes**

**Family - Charadriidae**

Genus - *Vanellus* Brisson,1760

Tails with broad black band and often with a narrow white terminal band.

17. *Vanellus indicus indicus* (Boddaert,1783) (Fig.5)

[Common name - Redwattled Lapwing]

Back and wings bronze-brown; head, neck and breast black; a creamson fleshy wattles in front of each eye; a broad white band behind eyes running down sides of neck and wings to meet the white underparts.

Genus - *Pluvialis* Brisson, 1760

Tail with narrowly barred; black spotted.

18. *Pluvialis dominica fulva* (Gmelin, 1789)

[Common name - Eastern Golden Plover] (Fig. 6)

Thick head, slender bare legs, pigeon-like bill; brown above, spangled with white and gold; whitish below mottled on breast with brown, grey, yellow; in breeding seasons plumage underparts black; axillaries grey.

Genus - *Gallinago* Brisson, 1760

19. *Gallinago gallinago gallinago* (Linnaeus,1758)

[Common name - Fantail Snipe] (Fig. 7)

Back dark brown, heavily streaked with black, rufous and buff; underparts whitish; Bill straight slender, about $2^1/_2$ inches in length, yellowish horny on basal half, dark horny brown on terminal half; Three outer pairs of tail feathers marked with dusky spots and bars; sexes alike.

Genus - *Calidris* Merrem,1804

Tibia unfeathered; toes divided; bill not spoon-shaped; and not sharply pointed; tip of bill slightly expanded.

20. *Calidris minuta* (Leisler,1812)

[Common name - Little Stint]

Back mottled greyish brown; underparts white; rump and middle tail feathers dark brown; outer tail feathers smoky brown; bill and legs black; wings with narrow wing bar; summer plumage richer - more black and rufous.

**Order - Apodiformes**

**Family - Apodidae**

Genus - *Apus* Scopoli,1777

Four toes directed forward though 1st reversible.

*21.* *Apus affinis affinis* (J.E.Gray,1830)

[Common name - Indian House Swift]

Crown brown, forehead more grey but no white and no trace of supercilium; bill horny black; throat and rump white; legs and feet pinkish brown.

Genus - *Cypsiurus* Lesson, 1843

Toes arranged in pairs, 3rd and 4th outward, 1st and 2nd inward.

22 *Cypsiurus parvus batasiensis* (J.E.Gray, 1829)

[Common name - Indian Palm Swift] (Fig. 8)

A small swift with narrow deeply forked tail; toes arranged in pairs, the 3rd and 4th toes out ward, the 1st and 2nd inward; wings long slender bow-like.

**Order - Coraciiformes**

**Family - Alcedinidae**

Genus - *Ceryle* Boie, 1828

Plumage black and white.

23. *Ceryle rudis leucomelanura* Reichenbach, 1851

[Common name - Indian Pied Kingfisher] (Fig. 9)

Medium sized bird (between Myna and Pigeon); plumage black and white; bill long and compressed; wings rather pointed; tail longer; it can be easily identified by its spectacular habit of "Standing on its tail" in mid-air, hovering over water; female similar to male but with a single black gorget broken in the middle, as against two more or less complete ones in the male.

Genus - *Alcedo* Linnaeus,1758.

Plumage not black and white; tail shorter than bill.

24. *Alcedo atthis bengalensis* Gmelin,1788

[Common name - Indian small Blue Kingfisher] (Fig. 10)

A small blue kingfisher with a white patch on side of neck; throat white, chest and belly light rusty coloured; bill long, straight and pointed; short stumpy tail.

**Family - Meropidae**

Genus - *Merops* Linnaeus,1758.

25. *Merops orientalis orientalis* Latham, 1801

[Common name - Indian Small Green Bee-eater] (Fig. 11)

Size equal to Sparrow. Back and underparts grass-green; head and neck tinged with reddish brown. Central pairs of tail feathers project beyond tail as blunt pins. Bill slender, long and slightly curved. Chin and throat verditer blue bordered by a black gorget.

**Order - Piciformes**

**Family - Picidae**

Genus - *Dinopium* Rafinesque,1814

Nostrils exposed. Mantle golden olive, not banded. Hallux small, about one-third length of 2$^{nd}$ toe or lacking.

26. *Dinopium benghalense benghalense* (Linnaeus,1758)

[Common name - Northern Goldenbacked Woodpecker] (Fig. 12).

In male, back golden yellow, neck; chin, throat and sides of neck black, finely streaked and stipped with black, more boldly on breast, crown and occipital crest cremson; in female, similar to male, but forehead black striped with white, only the occipital crest crimson.

**Order - Passeriformes**

**Family - Dicruridae**

Genus - *Dicrurus* Vieillot, 1816

27. *Dicrurus adsimilis albirictus* (Hodgson,1836)

[Common name - North Indian Black Drongo] (Fig. 13)

Large sized bird; entire body, the head and tail glossy jet black; tail long, deeply forked; white rictal spot present.

28. *D. caerulescens caerulescens* (Linnaeus,1758)

[Common name - Indian Whitebellied Drongo] (Fig. 14)

Head, back, tail and wings glossy indigo; throat, breast and belly brownish grey; under tail-coverts white; tail long and deeply forked.

**Family - Sturnidae**

Genus - *Acridotheres* Vieillot,1816

Distinct white wing-patch on the underparts of the base of the wings.

29. *Acridotheres fuscus fuscus* (Wagler,1827)

[Common name - Northern jungle Myna] (Fig. 15)

Size equal to common Myna, but greyish brown overall; wing with large white patch; forehead with a prominent tuft of erect black feathers at base of bill; tail broad white tipped; bill yellow-orange; legs and feet yellow-ochrea; In female cap dark grey.

**Family - Muscicapidae**

Genus - *Monticola* Boie,1822

Sexes dissimilar; tail shorter than wing; white on bases of secondaries and part of primaries; plumage largely with blue or bluish.

*30. Monticola cinclorhynchus* (Vigors,1832)

[Common name - Bullheaded Rock Thrush]

Size equal to Bulbul; a male with blue head throat and nape, wing with a white patch, shoulders blue; rump rufous, tail blackish blue; breast and belly orange rufous; female-head, back and tail olive brown; throat, breast and belly squamated whitish and dark brown.

31. *M. solitarius pandoo* (Sykes,1832)

[Common name - Indian Blue Rock Trush] (Fig. 16)

Size equal to Bulbul; in male, very bright, almost azure blue plumage in summer; tail and wings brown; in summer plumage are fringed with fulvous above, breast brown, belly white; in female grey-brown on back; throat and breast with fine dark shag-streaks; Rump barred with blackish.

**Family - Motacillidae**

Genus - *Motacilla* Linnaeus,1758.

Tail longer, upper plumage unstreaked.

32. *Motacilla flava beema* (Sykes,1832)

[Common name - Blueheaded Yellow Wagtail] (Fig. 17)

Size almost equal to a sparrow; slim, long-tailed bird; back olive; head pale grey; Supercilium prominent; chin and malar streak white.

**Family - Nectariniidae**

Genus - *Nectarinia* Illiger,1811.

Central rectrices not elongated; plumage in male metallic, female greenish below.

33. *Nectarinia asiatica asiatica* (Latham,1790)

[Common name - Indian Purple Sunbird] (Fig. 18)

Male with metallic dark blue and purple on back; throat and breast metallic purple, sides blue-green; abdomen dark purple separated from breast by a narrow, inconspicuous reddish brown band; pectoral tufts bright yellow and scarlet; female olive brown; throat, chest and abdomen dull yellow.

**Family - Ploceidae**

Genus - *Ploceus* Cuvier,1816

Bill short and stout, 1st primary minute,2nd,3rd , 4th and 5th longest.

34. *Ploceus philippinus philippinus* (Linnaeus,1766)

[Common name - Indian Baya] (Fig. 19)

In breeding male, crown yellow, upper parts dark brown streaked with yellow on back; breast yellow, abdomen cream buff; female, crown and back yellowish; buff streaked with dark brown; throat white, tinged with yellow; yellowish buff breast, belly cream buff; stout conical bill; short square-cut tail.

Genus - *Lonchura* Sykes,1832

Bill broad at base, stout; wing reaching almost in the middle part of tail.

35. *Lonchura punctulata punctulata* (Linnaeus, 1758)

[Common name - Indian Spotted Munia] (Fig 20)

Size-less than a house sparrow, chocolate-brown with faint pale shaft-streaks above; undertail coverts fulvous, rump barred with white; tail tawny-olive; sides of head, neck and throat chestnut; breast speckled black and white; belly white.

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Fig. 1. *Bubulcus ibis coromandus*

Fig. 2. *Egretta intermedia intermedia*

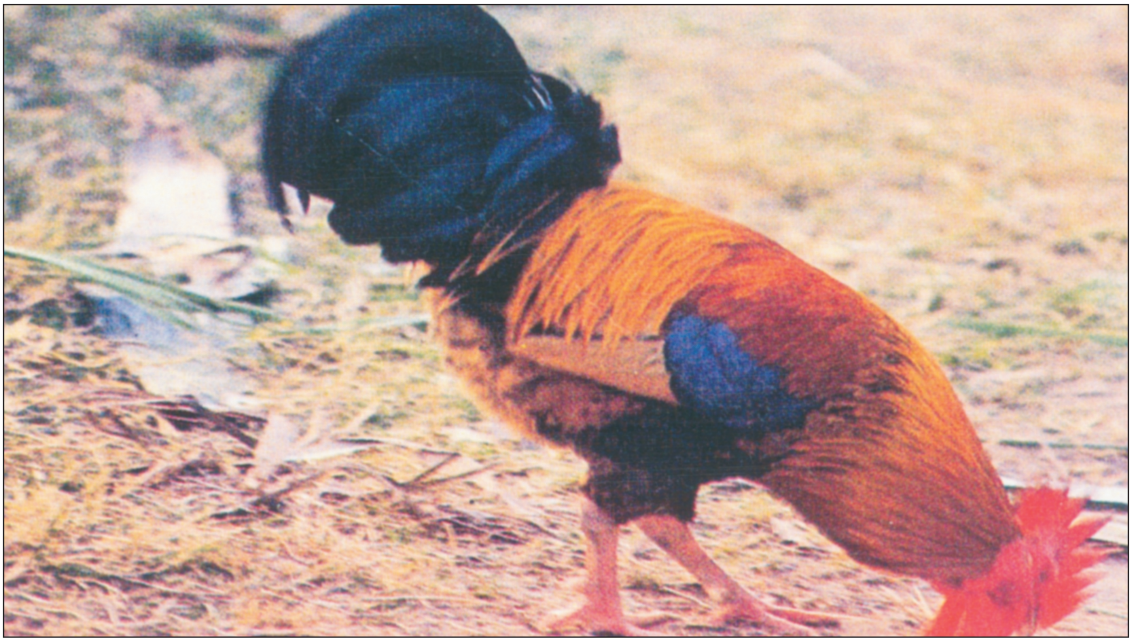

Fig. 3. *Gallus gallus murghi*

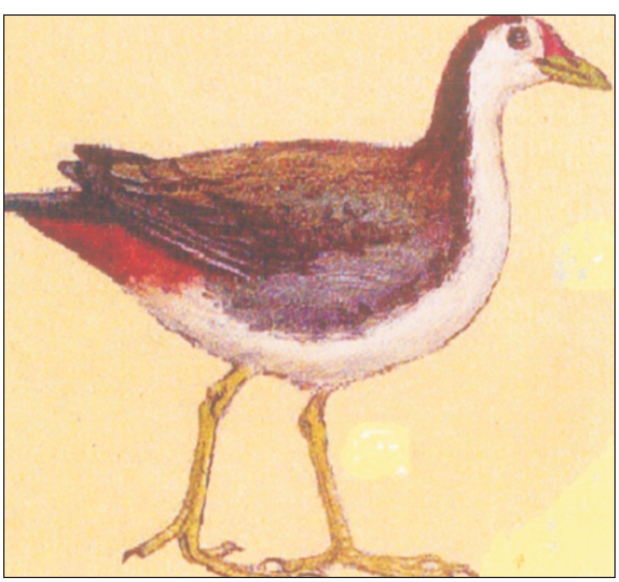

Fig. 4. *Amaurornis phoenicurus chinensis*

Fig. 5. *Vanellus indicus indicus*

Fig. 6. *Pluvialis dominica fulva*

Fig. 7. *Gallinago gallinago gallinago*

Fig. 8. *Cypsiurus parvus batasiensis*

Fig. 9. *Ceryle rudis leucomelanura*

Fig. 10. *Alcedo atthis bengalensis*

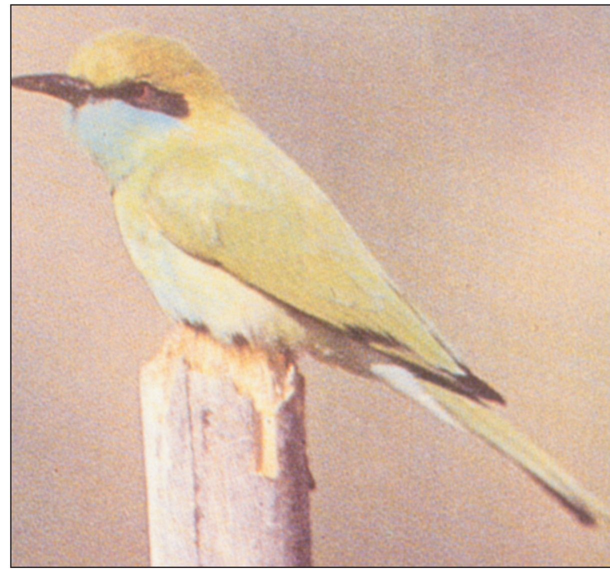

Fig. 11. *Merops orientalis orientalis*

Fig. 12. *Dinopium benghalense benghalense*

Fig. 13. *Dicrurus adsimilis albirictus*

Fig. 14. *Dicrurus caerulescens caerulescens*

Fig. 15. *Acridotheres fuscus fuscus*

Fig. 16. *Monticola solitarius pandoo*

Fig. 17. *Motacilla flava beema*

Fig. 18. *Nectarinia asiatica asiatica*

Fig. 19. *Ploceus philippinus philippinus*

Fig. 20. *Lonchura punctulata punctulata*

# Physico Chemical Parameters
# WATER

**P. Kaladharan, A. Nandakumar, K.K. Valsala and Ansy Mathew**

**1. *GLOBAL POSITIONING SYSTEM (*GPS)**

GPS is a space based all weather radio navigation system. Portable, handy model available operated by dry cells. It is also an indispensable device for G.I.S.

GPS provides precise information on

- Geographic position
- Velocity
- Time
- Altitude

GPS can be used in

A.Fixing/locating sampling stations

B.Determination of vegetative cover

C.Plankton collection (Distance of dragging and hauling the net at a known speed).

D. Digital mapping etc

**2.*TEMPERATURE***

Temperature is one of the important parameters affecting physico-chemical and biological changes in both water and sediment. Temperature shows diurnal and seasonal variations. Changes in the atmospheric temperature has a direct bearing on the surface of the water body. Hence simultaneous measurement of temperature from atmosphere and water surface is essential.

Water temperature at the surface is measured using a mercury filled Celsius thermometer with a graduation of 0.1$^{o}$ C. A bucket- thermometer is more convenient for measuring surface temperature with ease and accuracy.

**Note**

Separate thermometers should be used for measuring air and water temperatures. If only one thermometer is available in the field, air temperature must be measured first.

***3. LIGHT PENETRATION***

Secchi-disc is the commonly used instrument to measure the light penetration to subsurface depths. It is a 20 cm diameter circular metal plate. The upper surface is divided into four equal quadrants, located diagonally and painted alternatively in black and white colour. A staple is fixed at the center of upper surface for attaching a long graduated rope. On the lower surface weight is fixed in proper position incase requires, to facilitate easy immersion paint black colour in the lower side.

**Operation**:

The disc is lowered vertically into the water by releasing the graduated rope. The depth at which the Secchi-disc disappears is to be noted (d1) Then slowly lift the disc and again note the depth when it reappears(d2). The average of the two readings gives the depth of light penetration (Euphotic zone) which is expressed in cm.

**Calculation**:

$$\text{Depth of light penetration} \quad D \text{ cm} = \frac{d1 + d2}{2}$$

The symbol of Secchi disc extintion depth is ZsD

**Precaution**:

1. Keep Secchi disc surface always clean and bright.

2. Observation should be made when the sky is clear and bright and avoid shadows.

**4. *HYDROGEN ION CONCENTRATION (pH)***

**Principle:**

The pH of a solution is measured with a pH meter.

pH is the negative logarithem of the hydrogen ion concentration. Hydrogen ion concentration and pH are not the same. The former can be averaged; but pH being a log function should not be averaged. When the electrodes are dipped in two solutions of different pH levels and connected, a potential difference is set up between the two electrodes, which is measured by the Potentiometer. This is directly related to the pH of the solution.

**Procedure:**

1) Warm up the instrument for 15-20 minutes before use.
2) Calibrate the instrument with the standard buffer solutions, (pH 4, 7 or 9). Calibration is done by a buffer solution with the pH close to that of the sample.
3) Clean the electrode with double distilled water/ deionised water.
4) Immerse the electrode in the sample and stir for 3 minutes and record the pH.

**Note:**

Bring the sample to room temperature before measuring the pH.

**5. *SALINITY***

**Introduction:**

Salinity is usually estimated by either titrimetric method or using a salinometer. The method explained below is titrimetric.

**Principle:**

In this method the halogen ions in seawater are titrated with silver nitrate using potassium chromate as indicator. The halogen ions (except fluoride) readily react with silver to give insoluble silver halides. In this method silver will react with chromate only after all the halide ions, other than fluoride, are precipitated and as soon as a slight excess of silver ion is present, red silver chromate is formed. A faint red colour of the solution indicates the end point of the titration. The total quantity of silver nitrate required to react with chloride, bromide and iodide is a measure of the chlorinity of seawater.

**Reagents required:**

1) Silver nitrate (24.5 gm/l.)
2) Potassium chromate (10%)- 10 gm in 100 ml.
3) Standard seawater

**Procedure:**

Pipette out 10 ml of Standard seawater into a 250 ml conical flask. Add four drops of potassium chromate solution and using a mechanical stirrer titrate against silver nitrate solution. Repeat for accuracy/confirmation. Pipette out 10 ml of the seawater sample into the conical flask and proceed as above.

**Calculation:**

$$\text{Salinity of sample} = \frac{V_2 \times S}{V_1}$$

Where

$V_1$= Volume of silver nitrate for 10 ml standard seawater

$V_2$= Volume of silver nitrate used for titration of 10 ml sample

S = Salinity of Standard seawater

b) Potentiometric method:

Alternatively salinity of water samples can be measured using electronic instrument with appropriate electrode. Portable and handy instruments are available in the market.

**6. *DISSOLVED OXYGEN***

**(Winkler method)**

**Principle:**

Winkler method, depends upon the oxidation of manganous dioxide (bivalent manganese) by the oxygen dissolved in the sample resulting in the formation of a tetravalent compound. When the water containing the tetravalent compound is acidified, free iodine is liberated from the oxidation of potassium iodide. The free iodine is chemically equivalent to the amount of dissolved oxygen present in the sample and is determined by titration with a standard solution of sodium thiosulphate.

$$MnSO_4 + 2KOH \rightarrow Mn(OH)_2 + K_2SO_4$$

If the precipitate is white there is very little dissolved oxygen in the sample. A brown precipitate indicates that oxygen is dissolved in it and reacted with the manganous hydroxide to form manganic oxide.

$$2Mn(OH)_2 + O_2 \rightarrow 2MnO(OH)_2$$

On addition of acid, the precipitate is dissolved forming manganic sulphate.

$MnO(OH)_2 + 2H_2SO_4 \rightarrow Mn(SO_4)_2 + 3H_2O$

Due to an immediate reaction between this compound and the potassium iodide added previously, iodine is liberated resulting in the typical iodine colouration of the sample.

$Mn(SO_4)_2 + 2KI \rightarrow MnSO_4 + K_2SO_4 + I_2$

The number of molecules of iodine liberated by the reaction is equivalent to the number of molecules of oxygen dissolved in the sample and this can be determined by titrating against standard solution of sodium thiosulphate using starch as indicator.

$2Na_2S_2O_3 + I_2 \rightarrow Na_2S_4O_6 + 2NaI$

**Reagents:**

1) Sodium thiosulphate solution (1.25 gms in 1 ltr.)
2) Starch solution – 1gm starch made into a paste with distilled water and diluted to 100 ml, boiled and kept with 1 ml formalin as preservative.
3) Winkler solution A – 20 gms of manganous sulphate in 100 ml water.
4) Winkler solution B – 41 gm of sodium hydroxide + 25 gm of potassium iodide in 100 ml water.
5) Concentrated sulphuric acid.
6) Standard potassium iodate – Accurately weigh 0.1784 gm of potassium iodate into a 1 ltr. volumetric flask and dissolve and make up to the volume - (this is 0.005N)
7) Potassium iodide.

**Procedure:**

Collect the water sample in a 125 ml glass stoppered bottle without any air bubbles. Take out the stopper and add 1ml each of Winkler A and Winkler B solution. Close the bottle. Shake the bottle gently till the precipitation formed is evenly distributed. Allow settling. Then add 2 ml con. $H_2SO_4$; close bottle and gently shake till the precipitate is completely dissolved.

Pipette out 10 ml of potassium iodate solution into a conical flask. Add 1 gm of potassium iodide and 2 ml of conc. sulphuric acid. Dilute to 100 ml and titrate against sodium thiosulphate solution till the colour becomes pale yellow. Add 1 ml of starch solution, shake well and continue the titration till the blue colour disappears. Repeat the analysis

Pipette out 100 ml of the preserved sample and titrate against standard sodium thiosulphate as above.

**Calculation:**

$$\text{Normality of potassium iodate} = \frac{\text{Weight/litre}}{35.67} = N_1$$

$$\text{Normality of thiosulphate} = \frac{N_1 \times 10}{\text{Titrated volume of thiosulphate for 10 ml of potassium iodate}} = N_2$$

Hence amount of dissolved oxygen in ml/ltr. =

$$\frac{\text{ml. Thiosulphate} \times N_2 \times 8 \times 1000 \times R}{100 \times 1.429}$$

Where

R is the correction factor =1.01 i.e. 125/125-2

1.429 is the conversion factor from ppm to ml/lit.

**7. *DISSOLVED ORTHOPHOSPHATE***

***(Ascorbic acid method)***

**Introduction:**

Phosphorous present in seawater in the form of dissolved orthophosphate can be easily determined quantitatively based on the method given by Murphey and Riley, (1962).

**Principle:**

Ammonium molybdate and potassium antimony tartrate react in an acid medium with diluted solutions of orthophosphate to form phosphomolybdic acid that is reduced to the intensely coloured molybdenum blue by ascorbic acid. The intensity of the blue colour increases in proportion to the amount of phosphorous present and can be measured photometrically.

**Reagents:**

1) Sulphuric acid solution 5N: Dilute 70 ml concentrated $H_2SO_4$ with 500 ml distilled water.
2) Potassium antimony tartrate solution: dissolve 1.3715 g K (SbO) $C_4H_4O_6 \cdot ½H_2O$ in 400 ml distilled water in a 500 ml volumetric flask and dilute to volume. Store in a glass stoppered bottle.
3) Ammonium molybdate solution: Dissolve 20 g $(NH_4)_6 Mo_7 O_{24} \cdot 4H_2O$ in 500 ml distilled water. Store in a plastic bottle at 4º C.
4) Dissolve 1.76 g of ascorbic acid in 100 ml distilled water. This solution is stable.
5) Mixed reagent: Mix the above reagents in the following proportions. For 100 ml combined

reagent, 50 ml 5N $H_2SO_4$, 5 ml potassium antimony tartrate solution, 15 ml ammonium molybdate solution and 30 ml ascorbic acid solution. Mix after addition of each reagent. The reagent is stable for 4 hrs.

6) Standard stock phosphate solution: Dissolve accurately 0.816 gm of anhydrous potassium dihydrogen phosphate ($KH_2PO_4$) in 1000 ml of distilled water. Store in dark bottle with 1 ml of chloroform.1 ml of this solution contains 6µg of $PO_4$-P.

**Procedure:**

To 50 ml of the sample at laboratory temperature add 8.0 ml of mixed reagent. After 5 minutes and preferably within the first 30 minutes measure the extinction of the solution, in a 1 cm cell against distilled water at a wavelength of 885nm.

Warm another portion of the sample to laboratory temperature and measure the absorption to obtain turbidity correction. Correct the measured extinction of the sample by subtracting both the turbidity and reagent blank.

**Preparation of calibration graph:**

Dilute the standard stock solution to get working standards of 1.2, 2.4, 4.8, 7.2, 9.6 and 12.0 µg of $PO_4$-P/ ltr. concentrations. Follow the above procedure and measure the absorbance of the standards at 885nm. Draw a calibration graph.

**Calculation:**

Obtain the concentration of $PO_4$-P in the sample from the calibration graph.

**Note:**

1) Samples are to be collected in polythene bottles and analysis are to be carried out within an hour of collection. If the analysis are delayed then the samples must be frozen.
2) All the reagents must be in the room temperature before they are mixed and must be mixed in the order given. If turbidity forms in the mixed reagent shake and let it stand for a few minutes until the precipitate disappears before proceeding.
3) If the samples are high in phosphate, dilute them with distilled water before the reagents are added.

## 8. *REACTIVE SILICATE*

**Introduction:**

Silicon present in seawater in the dissolved form mainly as the alkali salts of orthosilicic acid $Si(OH)_4$, is estimated by the method described by Mullin and Riley (1955) and as modified by Strickland and Parsons (1968).

**Principle:**

Determination of Silicate in natural waters is based on the principle that yellow silicomolybdic acid is produced when silicomolybdates react with acids. But all forms of silica in solution will not react to give the silicomolybdate complex. Depending on the pH, the silicomolybdate complex exists in two isomeric forms (the alpha and beta silicomolybdic acids). The beta form is very unstable. The alpha form, termed 'reactive silicate' is the most available form, turns into a blue complex on reduction with ascorbic acid, which can be measured photometrically.

**Reagents:**

1. Acid ammonium molybdate: Shake 2 g of ammonium molybdate with approximately 70 ml of water, add 6 ml of conc. HCl to dissolve the salt completely. Dilute to 100 ml and if necessary filter. Since the reagent takes up silica from glass it should be stored in polythene bottles.
2. Oxalic acid: Dissolve 10 g of oxalic acid dihydrate in water, dilute to 100 ml and filter.
3. Sulphuric acid 25 % v/v
4. Metol-sulphite solution: Dissolve by shaking, 5g of metol in about 240 ml of water, containing 3g of anhydrous sodium sulphite and dilute to 250 ml. The solution, after filtration through a Whatman No.1 filter paper, should be stored in a dark glass bottle.
5. Reducing agent:

   Mix 100 ml of the metol sulphite solution with 60 ml of 10 % oxalic acid and add, while cooling, 120 ml of 25 % $H_2SO_4$, dilute to 300 ml. The fresh reducing agent should be prepared fortnightly.
6. Standard silicate solution: 0.960 g of sodium silico fluoride is dissolved in distilled water and make up to 1000 ml. 1 ml of this solution contains 5µg-of Si.

**Treatment of apparatus:**

Graduated flasks should be allowed to stand overnight with a mixture of concentrated nitric acid and sulphuric acids (1:1) to render them insoluble. After this treatment they should be thoroughly washed with tap water and distilled water. The flasks may be drained, but should not be allowed to become completely dry, as this may render them more soluble.

**Method:**

Pipette out 20 ml of the sample (up to 2 µg-**of** Si) – (If the sample contains more than 2 µg-of Si take 15 ml of seawater and add about 5 ml of distilled water) - into a 50 ml graduated flask containing 3 ml of the acid molybdate reagent and mix thoroughly. After 10 minutes add 15 ml of reducing agent and make up to 50 ml with distilled water. Allow to stand for 3 hours. Measure the optical density of the solution at 810 nm in a spectrophotometer. Use a reagent blank and set the instrument at 0.0 absorbance.

**Preparation of calibration graph:**

From the stock solution a series of working standards of known concentrations of silicates are prepared by suitably diluting with distilled water. The diluted working solutions of 2.5, 5.0, 10.0, 25.0, 50.0 and 100.0 µg-**of** Si/ lit. are prepared and treated with reagents and absorbance values are measured at 810 nm. Draw a calibration graph.

**Calculation:**

Concentration of the reactive silicate in the given sample is obtained from the graph.

**Note:**

1) Glass bottles must be avoided for sampling or storage; plastic containers are suitable. Because of the possible presence of siliceous organisms, storage in the dark is advised but analysis should in any case not be delayed for more than 24 hours. However if these are unavoidable, freezing of the sample would probably help to minimize changes.
2) For samples of salinity below 27‰, overnight standing after thawing is essential to allow silicon polymerized by freezing to depolymerize.

***9. NITRATE***

**Introduction:**

The estimation of Nitrate in seawater is based on a method by Morris and Riley (1963) with some modifications suggested by Grasshoff (1964) and Wood et. al. (1967).

**Principle:**

Nitrate in seawater is reduced almost quantitatively to nitrite when a sample is run through a column containing cadmium filings coated with metallic copper. The nitrite produced is determined by diazotizing with sulphanilamide and coupling with N- (1-naphthyl)-ethylenediamine to form a highly coloured azodye, which can be measured spectrophotometrically. Any nitrite initially present in the sample should be corrected .

**Special apparatus:**

A reduction column may be conveniently made.

**Reagents:**

1) Concentrated Ammonium chloride solution

   Dissolve 125 gm of AR grade ammonium chloride in 500 ml of distilled water and store in a glass or plastic bottle.

2) Dilute Ammonium chloride solution

   Dilute 50 ml of concentrated ammonium chloride solution to 2000 ml with distilled water. Store the solution in a glass or plastic bottle.

3) Cadmium-copper filings

   Cadmium filings of a specific size range are required for the columns. They may be brought or made from cadmium metal by filing the metal with a coarse wood file. Filings should pass through 2 mm mesh size and be retained by 0.5 mm mesh size. Stir about 100 g of fillings (sufficient for 2 columns with 500 ml of 2% w/v solution of $CuSO_4$ ($CuSo_4.5H_2O$) until the blue colour disappear in the solution. Place a small plug of copper wool (turnings) in the bottom of the reduction column and fill the column with diluted ammonium chloride solution.

Pour in slurry of the cadmium-copper filings and gently pack the column to the required height. Do not allow the filings to become dried out during the procedure. They should continue to be covered with diluted ammonium chloride or the seawater samples at all times. Wash the column thoroughly with diluted ammonium chloride and adjust the flow rate by tapping the side of the column so that about 100 ml is collected in 8-12 minutes. If the flow rate is slower than this, the column has to be re-packed. Add a small plug of copper wool to the top of the column.

The cadmium-copper filings may be reactivated after continued use (as judged by the F-value obtained for the standard). Filings are removed from the column, washed with 5% v/v HCl and then washed with distilled water until the pH of the decanted solution is >5. The filings can then be reactivated with copper sulphate using the procedure given above.

4) Sulphanilamide solution

Dissolve 5 g of sulphanilamide in a mixture of 50 ml of concentrated HCl (sp.gr.1.18) and 300 ml of distilled water. The solution is stable for many months.

5) N- (1-naphthyl)- ethylene diamine dihydrochloride solution

Dissolve 0.5 g of the dihydrochloride in 500 ml of distilled water. Store the solution in a dark bottle. The solution should be preapred afresh once a month or when a strong brown colouration develops.

6) Synthetic seawater

Dissolve 310 g of AR quality sodium chloride (NaCl), 100 g of AR quality magnesium sulphate ($MgSO_4.7H_2O$) and 0.5 gm of sodium bicarbonate ($NaHCO_3.H_2O$) in 10 lit. of distilled water.

7) Standard nitrate solution

Dissolve 1.02 g of AR quality potassium nitrate ($KNO_3$) in 1000 ml of distilled water. The solution should be stored in dark bottle and is generally stable in the absence of evaporation. Dilute 2.0 ml of this solution to 1000 ml with synthetic seawater.

This working solution should always be prepared afresh before use.

Concentration = 20µ g –of N/l.

**Procedure:**

Add 2 ml of conc. ammonium chloride to the sample. Transfer 100 ml of the sample into an Erlenmeyer flask. Mix the solution and pour about 5 ml on to the top of the column and allow it to pass through.

Add the remainder of the sample to the column and place the drained Erlenmeyer flask under the collection tube. Collect about 40 ml and discard. Collect about 50 ml in a graduated cylinder and dispense this into the Erlenmeyer flask, which contained the original sample. Allow the column to drain before adding the next 5 ml sample (as above).

To the 50 ml sample, add 1 ml of sulphanilamide solution from an automatic pipette. Mix and allow the reagent to react for more than 2 minute but less than 8 minutes. Add 1 ml of naphthylethylene diamine (NNED) solution and mix immediately. After 10 minutes and within 2 hrs. measure the extinction of the solution in a 1 cm cuvette against distilled water at a wavelength of 545 nm in a spectrophotometer. Correct the observed extinction with that of the reagent blank.

Carry out the procedure given above, using 100 ml of diluted Ammonium chloride instead of the seawater sample. Measure the absorbance using the same cuvette as is used for the samples and subtract the blank value from the sample values for each column.

Also carry out the procedure with 100 ml of the dilute standard nitrate solution. Measure the extinction for each individual column; then the factor F is

$F= 20/E_S$

Where

$E_S$ is the extinction of the standard corrected for the blank.

**Calculation:**

µg-of N/l = (Corrected extinction x F) – 0.95 C

Where 'C' is the concentration of nitrite in the sample in µ g-of N/l.

**Note:**

1) If the samples are stored they should be frozen at -20º C. In the presence of high concentrations of phytoplankton, samples should be filtered before analysis.
2) Because of the small salt effect, standard nitrate solutions should be made up in synthetic seawater or a low nitrate seawater sample should be 'spiked' with a standard amount of nitrate.
3) Column dimensions can be scaled down proportionally and smaller seawater samples can be used as required by users.
4) For extinction values of >1.0 or <1.0 use an appropriate cuvette cell length (i.e. 0.5 cm or 10 cm respectively) and adjust the factor which ever is appropriate.
5) In most samples of seawater, the level of nitrite will be insignificant and the correction can be largely ignored. However in some cases, particularly with respect to depth profiles where a nitrite maximum is expected, a correction should

be employed. The factor of 0.95 allows for an approximate 5% loss of nitrite on the column compared with the direct determination.

6) For the blank and standard values, the extinctions obtained should be applied to individual cadmium columns and not averaged. Each column may have small consistent differences that are allowed for only if the blank and standards are applied on an individual basis.

### *10. NITRITE*

Nitrite in water sample is determined by the similar method described for Nitrate determination except for reduction through Cadmium column. Hence reagents and procedure are same as those mentioned for Nitrate determination. Reduction through Cadmium column is not required.

Preparation of calibration graph:

Prepare a standard stock nitrite solution by dissolving 0.345 g of sodium nitrite in 1000 ml of distilled water (I ml = 5µg-of). 1 ml of stock solution is diluted to 100 ml with distilled water. Prepare dilutions of 0.05, 0.2, 0.5, 2.0, and 4.0µg-of/ltr and add the reagents. Measure the absorbance at 545 nm and prepare the calibration graph to obtain the nitrite concentration.

**Calculation:**

Concentration of the nitrite in the water sample is obtained from the calibration graph.

### 11. *AMMONIA*

**(Phenol hypochlorite method)**

**Introduction:**

For the determination of ammonia in the seawater the method involving indo-phenol blue reaction is well known and the one followed here is that of Zolarzano (1969).

**Principle:**

In this method phenol and hypochlorite react in an alkaline solution to form phenyl quinone-monoimine, which in turn, react with ammonia to form indophenol. Indophenol gives the solution a blue colour, the intensity of which is propotional to the concentration of ammonia present. Sodium nitroprusside is added to intensify the blue colour. Both ammonia and ammonium are measured, because in a strong alkaline solution all the ammonium is converted to ammonia. This procedure gives an estimate of total ammonia nitrogen.

**Reagents required:**

1) Phenol-alcohol solution: Dissolve 10 g of reagent grade phenol in 100 ml of 95% v/v ethyl alcohol.
2) Sodium nitroprusside 0.5%: Dissolve 1 g of sodium nitroprusside in 200 ml of water.
3) Alkaline solution: Dissolve 100 g of trisodium citrate and 5 g of sodium hydroxide in 500 ml of water.
4) Sodium hypochlorite solution: Use a solution of commercial hypochlorite, which should be atleast 1.5 N.
5) Oxidising solution: Mix 100 ml of sodium citrate solution (alkaline solution) and 25 ml of hypochlorite solution and use the same day (1:4 ratio- sodium hypo chlorite: alkaline solution).
6) Stock standard solution: 0.100 g of ammonium sulphate (A.R Grade) in 1000 ml of distilled water (1 ml = 1.5 µg of N).

**Procedure:**

The procedure consists of the successive addition of 2 ml of phenol solution, 2 ml of nitroprusside solution and 5 ml of oxidizing solution to 50 ml of sample mixing thoroughly after each addition. The colour is allowed to develop at room temperature (22-27º C) for 1 hr and the absorbance recorded at 640 nm in a spectrophotometer. Correct the absorbance with that of the reagent blank.

**Preparation of calibration graph:**

Dilute the standard stock solution to get working standards of 1.5, 3.0, 6.0, 9.0, 12, 15 µg of $NH_3$-N/ ltr. concentrations. Follow the above procedure and measure the absorbance at a wavelength of 640 nm in a spectrophotometer and draw a calibration graph.

**Calculation:**

Obtain the concentration of $NH_3$-N in the sample from the calibration graph.

**Note:**

1) All the reagents are prepared using ammonia free distilled water.
2) All the glasswares used must be cleaned by washing initially with warm dilute hydro-chloric acid and rinsing thoroughly with distilled water.
3) Filter the water sample prior to analysis through Whatman No: 42, or equivalent filter paper.
4) If the strength of hypochlorite is not satisfactory, a fresh reagent should be used for analysis.

***SOLIDS***

**(Total dissolved solids and Total suspended solids)**

**Introduction:**

Solids represent the portion of the water sample that is not lost upon evaporation. Solids include dissolved organic matter, particulate organic matter, dissolved inorganic matter / substances except gases, the carbon dioxide contained in bicarbonate and particulate inorganic substances.

**12. *TOTAL DISSOLVED SOLIDS (TDS)***

**Principle:**

To measure the total dissolved solids (TDS) concentration, a sample is filtered to remove the particulate matter, the filtrate is evaporated and the residue weighed. The TDS concentration indicates the milligram per liter of dissolved organic and inorganic matter in a sample

**Special Apparatus:**

Glass fiber filtration apparatus,

Gelman type A/E glass fiber filters or equivalent,

Imhoff cones,

100 ml evaporating dishes,

muffle furnace,

large desiccators

semi micro analytical balance.

**Procedure:**

Prepare glass fiber filters by soaking them in distilled water for 24 hrs. and then drying. Ignite a clean evaporating dish in a muffle furnace at 550º C for 30 minutes, cool the dish in a desiccator and weigh it. Position a filter holder in a suction flask, place a glass fibre filter on the holder, attach the funnel to the holder and attach the apparatus to a vacuum source. Mix the sample and filter 125-150 ml of it through the glass fiber filter.

Measure 100 ml of the filtrate into the tared evaporating dish with a graduated cylinder. Evaporate the contents of the dish in an oven at 95º C. Increase the oven temperature to 103º C for 1 hr. Cool the dish and residue in a desiccator and weigh.

**Calculation:**

$$\text{TDS (mg/ltr)} = \frac{(F-T)\,1000}{V}$$

Where

F= Final weight of Evaporating dish and residue in milligrams

T= Tare weight of evaporating dish in milligrams

V= Sample volume in milliliters

**13. *TOTAL SUSPENDED SOLIDS (TSS)***

**Principle:**

The Total Suspended solids (TSS) can be estimated by weighing the residue retained on the glass fibre filter used in the TDS analysis. The TSS in milligrams per litre is a measure of the particulate matter in suspension.

**Procedure:**

Prepare a glass fibre filter by soaking them in distilled water for 24 hours and then drying. Dry filters in oven at 80-90º C for 24 hrs. and tare. Pass a 100 ml (or larger) sample through the tared glass fibre filter. Remove the filter with small tongs (do not touch) and dry for 24 hrs. at 80-90º C. Cool the filter in a desiccator and weigh to five decimal places.

**Calculation:**

$$\text{TSS (mg/l.)} = \frac{(F-T)\,1000}{V}$$

Where F= Final weight of Filter and residue in milligrams

T= Tare weight of Filter in milligrams

V= Sample volume in millilitres

**Note:**

The TSS analysis can easily be conducted in conjunction with the TDS analysis.

Tare the filter used in the TDS analysis, determine the quantity of the residue resulting from the filtration of the TDS sample, and calculate TSS.

**14. *CHLOROPHYLL PIGMENTS***

**Principle:**

Chlorophyll bearing organisms present in known volume of water sample is filtered and dissolved in a solvent (Acetone 90% v/v). The pigment content dissolved in unit volume of acetone is measured spectrophotometrically. Since on an average, primary production in the ocean bears a fairly constant relation to the chlorophyll content, measurement of these pigments is also used as an index of productivity.

**Requirements:**

Glass fiber filter papers, vacuum-filtering unit, measuring jar, centrifuge and centrifuge tubes with cap.

**Method:**

Water samples collected for chlorophyll pigments must be passed through a coarse filter 0.2 mm mesh to remove zooplankton. Thoroughly mix the sample. A known volume (500 ml) of the sample is filtered through a 47 mm GF/C filter paper. The pigment is extracted by adding 10 ml of 90 % v/v acetone to each filter in a centrifuge tube. Tightly stopper the tube with aluminium foil or plastic cap. The extraction is carried out at low temperature for 20 hours in dark. The extract is centrifuged (6000 rpm for 8 minutes) and the final volume is adjusted to 10 ml with the same solvent. Decant the supernatant into a cuvette and measure the absorbance at the following wavelengths (750, 664, 647 & 630 nm). The amount of pigments in the sample is calculated using the revised formula of Jeffery and Humphrey (1975).

**Calculation:**

Chlorophyll a = 11.85 x **E** 664 – 1.54 x **E** 647 – 0.08 x E 630

Chlorophyll b = 21.03 x **E** 647 – 5.43 x **E** 664 – 2.66 x E 630

Chlorophyll c = 24.52 x **E** 630 – 1.67 x **E** 664 – 7.6 x E 647

Where

E stands for the absorbance at different wavelengths obtained above and corrected by the 750 nm reading; Chlorophyll a, b and c are the amounts of chlorophyll.

$$\text{Then mg Chlorophyll}/\text{m}^3 = \frac{C \times v}{V \times 10}$$

Where

v = volume of acetone used.

V= volume of sample in litres.

C = Amount of Chlorophylls a, b & c

**Note:**

Water sample must be frozen if filtration can not be done immediately. While filtration the sample should be mixed thoroughly.

***POTENTIOMETRIC METHOD OF DETERMINING WATER AND SEDIMENT CHARACTERISTICS***

For the easy and *in situ* measurement of physico-chemical parameters of water and sediment , different models of portable multi parameter meters are available for affordable price. These portable electronic instruments do contain besides the main unit, electrodes/probes for recording parameters such as

- Temperature
- Conductivity
- Salinity/Chlorinity
- PH
- Turbidity
- Dissolved oxygen
- Redox potential

**Advantages**:

The measured parameters can be stored and recorded through a printer in the laboratory .

The portable instruments ensure speedy, *in situ* and accurate measurement of different parameters of water and sediment

The instruments eliminate the risk of storage , transportation and preservation of large number of samples

These instruments can save the recurring expenditure needed for chemicals, costly reagents and sample containers.

# Estimation of Primary Productivity (Modified Light and Dark bottle Oxygen method)

**G.S.D. Selvaraj**

**Principle:**

This method is based on the estimation of dissolved oxygen in the water samples (ml/l) by Winkler's method. Three BOD bottles are used for this purpose. The DO content in the initial (I), Dark (D) and Light (L) bottles with a capacity of 125 or 250 ml after specific incubation period are utilized to calculate the primary productivity. The incubation period various with the nature of water sample such as 3.0 hours for sea water whereas 2.5 hours for shallow estuarine water. The incubation is done in light for the same in 'L' bottle and in dark 'D' bottle, while sample in I bottle is fixed by winkler 'A' and 'B' at the initial stage of experiment. Gross Primary (Photosynthetic) Production (GPP) is determined by using L-D values extrapolated for 12 light hours of the day. Net Primary (Photosynthetic) Production (NPP) of oxygen is obtained from either L-I or 0.8 (L-D) value ( calculated for 12 light hours of the day) whichever comes closer to (but less than) L-D value. If the L-I value falls much below 0.8 (L-D) value, it indicates that bacterial interference ( other biochemical oxidation process ) is more in the water samples. At times, L-I value exceeds L-D value. In such cases , 0.8 (L-D) value should be taken into account to assess NPP.

**Reagents required:**

All the reagents used in Winkler's method to determine dissolved oxygen (ml/l) in water samples.

**Note:** Normality of Sodium thiosulphate solution should not exceed 0.005 (for more accuracy).

**Procedure:**

Filtered water samples through zooplankton filters (0.4mm mesh size) are preferred in Primary productivity experiments to minimise the interference of zooplankton and suspended particles. Water samples are collected in plastic bucket and kept undisturbed for few minutes for uniform distribution of phytoplankton. Collect water samples always in the series of 'L', 'D' and 'I' labelled 125 or 250 ml BOD glass bottles without entangling air bubbles and close the lids gently. The filtered water samples thus collected are set for incubation atleast 30 minutes (30 minutes to one hour) after sampling to bring the micro organisms physiologically stabilized inside the 'I', 'D' and 'L' bottle. Fix the 'I' bottle with Winkler 'A' and 'B' reagents and keep the 'L' bottle exposed to uniform light and 'D' bottle in darkness (enclosed in dark bags or wrap with thick black cloth or any similar material) in the Laboratory or Research Vessel under simulated *in situ* environment at room (normal) temperature during incubation time. Fix 'L' and 'D' bottles after incubation time with Winkler 'A' and 'B' and determine dissolved oxygen values upto three decimal points for 'I', 'D' and 'L' bottle samples.

**Calculation:**

GPP = (L-D) value in ml $O_2$/ l per 12 light hours per day

NPP = (L-I) or 0.8 (L-D) value in ml $O_2$/ l per 12 light hours per day (whichever is applicable)

For uniformity, 0.8 (L-D) per 12 hrs may be considered for NPP.

*Conversion factor:* 1 ml $O_2$ released by photosynthesis is equivalent to 0.536 mg C.

Average photosynthetic Quotient (PQ) =1.25

Hence , 1 ml $O_2 = \frac{0.536}{1.25} = 0.429$ mg. C.

GPP or NPP value of oxygen (ml $O_2$/l/D) multiplied by 0.429 would give the Primary (Photsynthetic) Productivity value in mg.C/l/d.

**Note:** If the oxygen value obtained for GPP/NPP is in mg $O_2$/l , then 1 mg $O_2$ released = 0.375 mg.C, which , when divided by the PQ(1.25) , would give 0.3 mg.C.

GPP or NPP value of oxygen (mg $O_2$ /l/d) multiplied by 0.3 would give the Primary (Photosynthetic) Productivity value in mg.C/l/d.

mg.C/l/d = g.C/$m^3$/d

Primary productivity values of surface water samples are normally expressed in g.C/$m^3$ /d . If the value is very less, this may be converted into mg.C/$m^3$/d.

**Assessment of column production:**

To determine the column production of the euphotic zone, collect water samples at different depths using Casella or Nansen's Water Sampler and conduct simulated *in situ* incubation experiments as cited above. Assess the GPP and NPP values at different depths and calculate the values as follows:

Column Production (g.C/$m^2$ /d) =

$$\frac{f}{1000} \times \left[\frac{(a+b)}{2}(d_1-d_0)\right] + \left[\frac{(b+c)}{2}(d_2-d_1)\right] + \text{———}$$

where, f = Factor = 1 ( for *in situ* and simulated *in situ* experiments.)

a,b,c,d = GPP/NPP values in mg.C/$m^3$/d.

$d_0, d_1, d_2$ $d_3$ = Depth in meters ($d_0$= surface)

1000 = To convert mg.C into g.C. value

**Note:** For shallow culture ponds (less than 2m depth), half the surface production (GPP/NPP) value (g.C/$m^3$/d) is considered as the Column Production of the pond (g.C/$m^2$/d).

## Suggested References

Kaladharan. P., D. Prema, A. Nandakumar and K.S. Leelabhai, (2001). *Manual of Analytical Methods for Seawater and Sediment*, 51 pp. CMFRI, Cochin

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Strickland, J.D.H. and T. R. Parsons (1972). *Bull. Fish. Res. Bd. Canada*,167:310 pp.

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# Assessment of BiochemicalOxygen Demand (BOD) in Tropical Aquatic Systems (Modified)

G.S.D. Selvaraj

**Introduction :**

The procedures adopted to determine BOD in tropical coastal water bodies are complicated and time consuming resulting in practical difficulties. The results do not give the realistic picture of the existing environment and also do not meet the immediate need at times of emergency due to the drawbacks such as incubation at $20^0$C for five days for tropical water samples. Hence, development of a simplified method to assess BOD is a prerequisite for tropical waters.

**Principle:**

This simplified method does not require BOD incubator as the BOD values are obtained after 24 hours of incubation at room temperature. This would indicate the extent to which biochemical oxygen demand is there in the aquatic system much closer to reality. Winkler method is followed to fix the 'I' bottle and 'D' bottle samples. The difference in the oxygen values obtained between Initial and Dark bottle samples for 24 hours would give the BOD value ( ml $O_2$/ l) per day.

**Reagents:**

All the reagents used for estimation of dissolved oxygen by Winkler method.

**Procedure:**

Collect water samples in 'I' and 'D' labelled BOD glass bottles of 125 or 250 ml capacity in duplicate without entangling air bubbles. Fix the 'I ' labelled bottle samples with Winkler ' A' and 'B 'and keep the 'D' labelled water samples inside the dark bag and place them in a trough of water at room temperature and fix the 'D' labelled samples after 24 hours. Note the initial and final time and estimate the dissolved oxygen values of 'I' and 'D' bottles. Find out the difference between 'I' and 'D' value per 24 hours. Calculate the average BOD value of the duplicate samples in ml $O_2$ / l/ day or mg $O_2$ / l /day. To convert oxygen value from ml/l to mg/l, values in ml/l are divided by 0.7

BOD( ml $O_2$/ l/d) = (I-D) oxygen value per 24 hrs.

**Note:** (1). This result does not include photosynthetic release of oxygen in water of that day.

(2) Wherever primary productivity experiments (by L & D bottle oxygen technique) are not possible to conduct , this method can be followed to assess BOD in tropical water bodies which gives the result on the next day , much closer to reality.

**Suggested References**

Kaladharan. P. , D. Prema, A.Nandakumar and K.S. Leelabhai,2001. Manual of Analytical Methods for Seawater and Sediment, p19-21. CMFRI, Cochin.

Selvaraj , G.S.D., 1997.Proceedings of the National Seminar on Water quality issues in Aquaculture Systems,p.139-146. Fisheries College, Tuticorin.

# Determination of Net Gain / Loss of Oxygen by Biochemical Processes in Tropical Waters

**G.S.D. Selvaraj**

## Introduction :

Biochemical role involving photosynthesis, respiration and other oxidation-reduction processes such as decomposition of organic matter and recycling of minerals by bacterial action influence the rate of production and consumption of dissolved oxygen in tropical aquatic ecosystems. In the existing method of BOD and COD estimations , the biochemical release of oxygen in water by photosynthesis and consumption by respiration of phyto and zooplankton are not considered while assessing the biochemical oxygen demand in aquatic systems. This method helps to assess the net loss/gain of biochemical oxygen consumption / production in the water samples considering the microbio-chemical processes involving release of oxygen by photosynthesis, consumption by respiration of micro-organisms and other biochemical oxidation – reduction processes in water.

## Principle:

This modified L & D bottle oxygen technique, with 3 - 4 hours of incubation of Light and Dark bottles, helps to assess the net rate of biochemical consumption / production of oxygen assuming that L-I per 12 hrs (extrapolated value) gives the net rate of production / consumption of oxygen during 12 light hrs and D-I per 12 hrs would give the values for the 12 dark (night) hrs of the day.

## Procedure :

Collect water samples in ‘I’, ‘D’ and ‘L’ bottles (BOD glass bottles) in duplicate . Fix the ‘ I’ bottle samples with Winkler ‘ A’ and ‘B’ and give incubation of 3-4 hours to ‘L’ and ‘D’ bottles . Note the initial and final time of simulated *in situ* experiment . Estimate oxygen for ‘I’, ‘D’and ‘L’ bottle samples. Extrapolate L-I value for 12 hours and D-I value for 12 hours. The difference in the oxygen values obtained between ‘L’ and ‘I’ bottles (L-I) for 12 light hours was considered for the net result of biochemical oxygen production by phytoplankton and bacteria together (+value) or consumption (- Value) for the day time. The ‘D’ and ‘I’ bottles (D-I) per 12 hours to indicate the net result of biochemical oxygen production (+ value) or consumption (- value) during night time. Commutation of these oxygen values (plus and minus values) thus obtained for the day and night hours [(L-I) +(D-I)] would give the net rate of biochemical production (+ value = net gain) or consumption (- value = net loss) of oxygen in the water samples per day (24 hours). If the net gain/loss of oxygen values are expressed per hour , the values may be given upto four decimal points ( for more accuracy).

## Note :

1. Using the data of this experiment, gross and net primary production can also be estimated adopting the formula (L-D) per 12 hours and 0.8 (L-D) per 12 hours respectively. The respiration by photosynthetic organisms would be 0.2 (L-D) for 12 light hours and 0.4 (L-D) for 24 hours of the day. As a result, net photosynthetic production of oxygen for 24 hours of the day would be 0.6 (L-D) per 12 hours.
2. This method helps to assess the water quality indicating whether and to what extent the aquatic environment is in the oxidizing or reducing state.

## Suggested References

Selvaraj, G.S.D. (1997). *Proceedings of the National Seminar on Water Quality Issues in Aquaculture Systems.* p.139-146. Fisheries College, Tuticorin.

Selvaraj, G.S.D. (2000). *Seaweed Res.Utiln.,* **22***(1&2):* 81-88.

Selvaraj, G.S.D. (2002). *Proc. Natl. Sem. Devt. Tran. Fish. Tech.*, p.59-65. Fisheries College, Tuticorin.

# Sediment Analysis

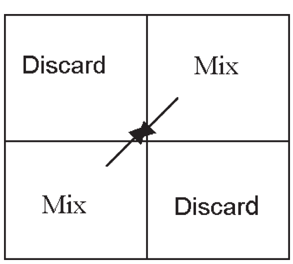
**D. Prema, K. S. Leela Bhai and P. K. Jayasurya**

### *1. SEDIMENT SAMPLING AND PROCESSING*

**Sediment sampling:**

Sediment sample is collected from the stations (seaside, river mouth and within the Mangroves, depending on the topography and area and upper reaches of river) using a grab.

Sample should be representative of the area sampled. For this, collect samples from at least four sites in a station. Pool these samples in a wide basin. The pooled sediment is mixed thoroughly. Then quartering is done, removing the opposite quarters as shown below.




Quartering of sediment sample

Quartering is done till a sizeable quantity i.e., around 500 g sediment is obtained. Collect in heavy-duty plastic bags.

**Sediment processing:**

Do not store the sediment wet for more than one day. Wet samples should be kept under refrigeration if storage is needed in the wet stage for more than one day. Then air-dry the sediment in shade in well-ventilated places. To reduce drying time, oven drying can be done at 50-60°C. (Temperature should not be increased above 60°C since it will cause loss of nutrients). Then pulverize the sediment gently by breaking clods using a pestle and mortar. (Do not over grind the sediment so as to break the sand particles, which will cause errors in textural analysis). Then sediment samples can be stored in well-labeled, capped plastic bottles or heavy-duty plastic bags. At this stage, it is ready for analysis. While storing, store in a dry place.

### *2. HYDROGEN ION CONCENTRATION (pH)*

**Principle:**

The degree of acidity or alkalinity in soils also known as soil reaction is determined by hydrogen ion ($H^+$) concentration in soil solution. An acid soil has more $H^+$ than $OH^-$ ions, whereas basic or alkaline solution contains more $OH^-$ ions than $H^+$ ions. To categorize these conditions, the term soil pH is used.

**Determination of dry pH of sediment**

**Procedure:**

Calibrate the pH meter with buffer solution according to the maker's instructions and wash the electrode well.

To a 10 g air dried sediment sample add 25 ml water. The suspension is stirred at regular intervals for 20-30 min. Then pH is measured with glass electrode. The suspension is stirred just before electrode is immersed.

**Determination of wet pH of sediment**

**Procedure:**

Wet pH is to be determined before air-drying the sediment. After calibrating the pH meter, insert the electrode of the pH meter directly in to a wet lot of sediment sample and the pH recorded is the wet pH of the sediment.

### *3.Oxidation Reduction Potential (Eh) (Redox ptential)*

Oxidation Reduction Potential (Eh) is a quantitative measure of the tendency of a system to oxidize or reduce susceptible points. When Eh is positive and high it is an oxidizing system. When Eh is negative and low it is a reducing system.

Oxidation Reduction Potential of a fresh sediment can be determined using an ORP meter or using a pH meter with a compatible ORP electrode. After calibrating the ORP meter or the pH meter with the ORP electrode, using the suitable ORP buffer, wash the electrode well. Then insert the ORP electrode into the fresh sediment and note the reading of Eh.

## 4. SALINITY

**Principle:**

When standard silver nitrate solution is added to the soil extract, the chlorides will be precipitated as silver chloride. When all the chlorides being precipitated, next drop of silver nitrate will react with potassium chromate giving red colour of silver chromate.

**Reagents:**

(1) Silver nitrate (0.144 *N*): Dissolve 24.5 g of silver nitrate in 1 litre water.

(2) Indicator: 10 % potassium chromate.

**Procedure:**

Weigh 5 g of sediment and transfer it in to a conical flask. Add 25 ml distilled water and shake it for 30 minutes. The sample is then filtered through No.42 filter paper. To 10 ml of the filtrate is added 4 drops of 10 % potassium chromate indicator. This is then titrated against silver nitrate. The end point is the colour change from pale yellow to pale pinkish red. The salinity of the filtrate can alternatively be determined using appropriate probe of a salinometer or multiparameter instrument after calibration.

**Calculations:**

1 ml of 1*N* $AgNO_3$ = 35.46/ 1000 g of Cl

$$\text{Salinity} = \frac{X \times 0.144 \times 35.46 \times 25 \times 1000}{10 \times 5 \times 1000} \text{ g/kg}$$

$$= \frac{X \times 0.144 \times 35.46 \times 25}{10 \times 5} \text{ mg/g or ppt}$$

where

| | | |
|---|---|---|
| X | = | volume of $AgNO_3$ used |
| 0.144 | = | normality of $AgNO_3$ |
| 35.46 | = | eq.wt of Cl |
| 25 | = | distilled water used for extraction |
| 10 | = | volume of extractant used for titration |
| 5 | = | quantity of sediment taken. |
| 1000 | = | for converting 35.46mg to g |
| 1000 | = | for converting g to kg |

**Interstitial salinity** : Interstitial salinity can be determined by inserting the salinity probe of a salinometer or multiparameter instrument (after calibration) into the fresh sediment.

## 5. SOIL TEXTURE

***(Mechanical Analysis by International Pipette Method)***

**Principle:**

Mechanical analysis is defined as the analytical procedure by which individual particles are separated to determine the size distribution of the soil. According to the relative proportion of various sizes of the individual particle, they are separated in to various groups and is known as textural classification of soil. According to International society of soil science system, the mechanical separates of soil are classified as follows.

| Soil separate | Diameter limit (mm) |
|---|---|
| Coarse sand | 2 to 0.2 |
| Fine sand | 0.2 to 0.02 |
| Silt | 0.02 to 0.002 |
| Clay | < 0.002 |

Mechanical analysis consists essentially of two distinct operations:

1) Dispersion: The most important cementing agents are organic matter, colloidal clay and dehydrated colloidal oxides of Fe, Al.

   The important physical techniques that have been used to effect the mechanical disruption of aggregates in to completely dispersed particles are shaking, stirring and boiling etc.

The chemical aid in soil dispersion are based on

(a) Oxidation of organic matter by $H_2O_2$; (b) Removal of flocculating ions by introducing single cations; (c) Peptization of colloidal particles through the introduction of ions that increase negative potential.

2) Fractionation of the sample in to various separates: The relation between the particle size and its rate of fall through a fluid is expressed by Stokes law as follows:

   $V = 2gr^2(dp\text{-}dw)/9\eta$

Where, V = velocity of fall of particles, r = radius of particles, dp = density of particles, dw = density of medium, $\eta$ = coefficient of viscosity of liquid and g = acceleration due to gravity.

**Pipette method:**

According to this method, instead of completely separating the fractions of the mechanical compositions, suspension samples are taken from the different depths subsequent to shaking, after the lapse of certain predetermined period of settling which are dependent on the dimensions of the mechanical elements and on the temperature of water.

**Procedure:**

To the wet sediment add 10 ml of 1*N* HCl and 10 ml of 6% $H_2O_2$. Stir it till the effervescence stops. Add 100 ml of distilled water and allow settling. The supernatant liquid is decanted after one day. The process is continued for several times till the supernatant liquid is chloride free. The sediment is then air dried, pulverized and sieved through a 2mm mesh sieve to obtain the size fraction of sand and finer particles. Weigh 20 g of the sieved sediment and it is wet sieved into 500 ml sedimentation cylinder using a 230 mesh sieve. Sediment retained in the sieve is dried and weighed to obtain the sand fraction. Add 10 ml of 1*N* NaOH to the cylinder and make up to 500 ml. The cylinder is shaken for 10 minutes. Draw 10 ml of suspension using a pipette at a depth of 20 cm after 4 minutes into a weighed petridish. Dry it at 105º C to constant weight. Difference in weight will give the quantity of clay + silt in 10 ml suspension. The whole suspension is again shaken and kept undisturbed. After 6 hrs. and 15 minutes, draw 10 ml suspension in a similar manner as described earlier in a weighed petridish and then dry at 105ºC until constant weight is attained.

**Calculation:**

(a) % of sand = Wt. of sand x 100 / 20

(b) Silt + clay fraction:

Total volume of suspension = 500 ml

Volume of suspension taken = 10 ml

% silt + clay = (Wt of silt + clay ) x 500 x 100 /10 x20

(c) Clay Fraction:

% Clay = Wt. of clay x 500 x100/10 x 20

(d) % silt = (% silt +clay) - % clay

***6. ORGANIC CARBON***

***(Walkley and Black's titration method)***

**Principle:**

The soil is digested with potassium dichromate solution and sulphuric acid making use of the heat of dilution of sulphuric acid. The excess of potassium dichromate not reduced by the organic matter of the soil, is determined by titration with standard ferrous sulphate or ferrous ammonium sulphate solution.

**Reagents:**

1) Potassium dichromate 1*N*: Dissolve 49 g of potassium dichromate in water and make it to 1 litre.

2) Sulphuric acid + silver sulphate: Dissolve 25 g of silver sulphate in 1 litre of conc. sulphuric acid.

3) Phosphoric acid (85%)

4) Diphenylamine indicator solution: Dissolve 0.5 g of diphenylamine in a mixture of 100 ml sulphuric acid and 20 ml water and store in a colored bottle.

5) Ferrous ammonium sulphate (*N*/2): Dissolve 196 g of A.R grade $FeSO_4\,(NH_4)_2SO_4 \cdot 6H_2O$ in water. Add 20 ml sulphuric acid and dilute to 1 litre.

**Procedure:**

Take 0.5 – 2 g of soil (0.5 mm sieved) in 500 ml conical flask. Add 10ml of 1*N* potassium dichromate and 20 ml conc. $H_2SO_4$. Shake well for a minute or two and allow it to stand for about 30 minutes. Add 200 ml water, 10 ml phosphoric acid and 1 ml diphenylamine indicator solution. A deep violet color will appear. Titrate with *N*/2 ferrous ammonium sulphate solution, till the violet color changes to blue and finally to green. In the same way carry out a blank determination also and calculate the results as follows:-

**Calculation:**

Weight of soil taken = W g

Volume of 0.5 *N* ferrous ammonium sulphate required for reducing 10 ml $K_2Cr_2O_7$ solution (Blank Reading) = X ml

Volume of 0.5 *N* ferrous ammonium sulphate required for reducing the excess of dichromate (experimental reading) = Y ml

Difference = (X–Y) ml

1 ml of 1*N* $K_2Cr_2O_7$ = 0.003 g carbon

$$\% \text{ of carbon in soil} = \frac{(X-Y) \times N \times 0.003 \times 100}{W}$$

Where N = normality of ferrous ammonium sulphate

**7. Extraction of ammonia, nitrate and nitrite in sediments**

The ammmoniacal nitrogen, nitrite nitrogen and nitrate nitrogen can be together extracted with one reagent ie, 2*M* KCl solution.

**Reagent**:

2 *M* Potassium chloride solution:

Dissolve 150 g of KCl in 1000ml of distilled water

**Procedure** :

Shake 15g fresh sediment in 150ml of 2 *M* KCl for 1 hour and allow to settle. Filter the supernatant through Whatman no.1 filter paper. The filtrate can be used for determination of ammoniacal nitrogen, nitrite nitrogen and nitrate nitrogen.

***7a. Determination of $NH_3$ – N***

***(Phenol hypochlorite method)***

**Principle**:

In this method phenol and hypochlorite react in an alkaline solution to form phenyl quinone-monoimine, which in turn, react with ammonia to form indophenol. Indophenol gives the solution a blue colour, the intensity of which is propotional to the concentration of ammonia present. Sodium nitroprusside is added to intensify the blue colour. Both ammonia and ammonium are measured because in a strong alkaline solution, all the ammonium is converted to ammonia. This procedure gives an estimate of total ammonia nitrogen.

**Reagents :**

1. Phenol-alcohol solution: Dissolve 10g of reagent grade phenol in 100ml of 95% v/v ethyl alcohol, U.S.P or methyl alcohol.
2. Sodium nitroprusside 0.5%: Dissolve 1g of sodium nitroprusside in 200ml of water.
3. Alkaline solution: Dissolve 100g of trisodium citrate and 5 g of sodium hydroxide in 500ml of water.
4. Sodium hypochlorite solution : Use a solution of commercial hypochlorite, which should be atleast 1.5*N*.
5. Oxidising solution: Mix 100ml of sodium citrate solution (alkaline solution) and 25ml of hypochlorite solution and use the same day (1:4 ratio – sodium hypochlorite : alkaline solution)
6. Stock standard solution: 3.147g ammonium chloride dissolved and made up to 1000ml. This gives a 1000 ppm solution of $NH_3$ N.

**Procedure**:

The procedure consists of the successive addition of 2ml of phenol solution, 2ml of nitroprusside solution and 5ml of oxidizing solution to 50ml of sample mixing thoroughly after each addition . The colour is allowed to develop at room temperature (22 -27ºC) for 1hr and the absorbance is recorded at 640 nm in a spectrophotometer. Correct the absorbance with that of the reagent blank.

**Preparation of Calibration graph**:

Dilute the standard stock solution to get working standards of 0.1, 0.2, 0.3, 0.4, 0.5 ppm of $NH_3$ – N concentrations. Follow the above procedure and measure the absorbance at a wavelength at 640 nm in a spectrophotometer and draw a calibration graph.

**Calculation:**

Obtain the concentration (ppm) of $NH_3$ – N in the sample from the calibration graph.

$NH_3$ – N = ppm x150/15

**Note:**

1. All the reagents are to be prepared using ammonia free distilled water.

   All the glasswares used must be cleaned by washing initially with warm dilute hydro-chloric acid and rinsing thoroughly with distilled water.
2. If the strength of hypochlorite is not satisfactory, a fresh reagent should be used for analysis.

***7b. Determination of $NO_3$ and $NO_2$ :***

**Nitrate**

**Reagents**:

1. Phenol solution:

   Dissolve 46g of dry A.R. Quality phenol in 1000ml of distilled water. It is stored in a glass bottle tightly stoppered.
2. Sodium Hydroxide:

   Dissolve 29 ± 0.5 gms of A.R. quality Sodium Hydroxide in distilled water. Cool and dilute to 2000 ml.
3. Buffer Reagent:

   Pipette out 25ml of Phenol solution into a dry beaker and add 25ml of sodium hydroxide solution. The solution is stable for one hour.

4. Copper Sulphate Solution:

   Dissolve 0.1 g of A.R. copper sulphate in 1000ml of distilled water.

5. Hydrazine Sulphate Solution:

   Dissolve 14.5 g of A.R. quality hydrazine sulphate in 2000ml of distilled water. Store in a dark glass bottle. The solution is stable for one month.

6. Reducing Agent:

   Mix 25 ml of copper sulphate solution and 25ml of Hydrazine sulphate solution in 50ml measuring cylinder. The solution is stable for one hour.

7. Acetone:

8. Sulphanilamide Solution:

   Dissolve 5 g of Sulphanilamide in a mixture of 50 ml concentrated Hydrochloric acid and about 300ml distilled water. Dilute to 500 ml with water. It is stable for a few months.

9. N1-Naphtyl Ethylene Diamine Di-Hydrochloride Solution (N.N.E.D):

   Dissolve 0.5 g of N.N.E.D. in 500ml distilled water. Store the solution in a dark bottle.

10. Standard Nitrate solution:

    Dissolve 1.629g of analytical reagent quality potassium nitrate in 1000 ml. This gives 1000 ppm of nitrate nitrogen. Prepare working standards of 0.02, 0.03, 0.04, 0.05, 0.06 ppm and prepare a calibration graph. From the calibration graph find out the ppm of nitrate nitrogen in the sample.

**Procedure:**

Measure out 50 ml of the filtrate with a 50 ml measuring cylinder into a 250 ml conical flask. Add 2 ml of buffer reagent and mix. After the buffer has been added to all the samples, add with rapid mixing 1.0 ml of reducing agent and keep the flasks away from sunlight in a dark place for about 20hrs. Add 2ml of acetone, and after 2 min. add 1 ml of sulphanilamide solution. After 2 minutes, but not later than 8 minutes add 1 ml of N.N.E.D solution and mix. Take reading at 545 nm . The calculated ppm is ($NO_3$ + $NO_2$). Deduct the $NO_2$ (ppm) from this to get $NO_3$ alone.

**Calculation**

$NO_3$ alone = [ ($NO_3$ + $NO_2$) ppm x150/15] – $NO_2$ ppm. x 150/15.

**7c. Nitrite**

**Reagents:**

1. Sulphanilamide solution ( as in Nitrate method)
2. N1 Napthyl Ethylene Diamine Dihydrochloride (N.N.E.D.) (As in Nitrate method)
3. Standard Nitrite Solution:

Dissolve 1.5 g of A.R. Sodium Nitrite in 1000 ml of distilled water. Store in a dark bottle with 1 ml of Chloroform. This gives 1000 ppm solution of nitrite nitrogen. Prepare working standards of 0.02, 0.04, 0.06,0.08, 0.1ppm and prepare a calibration graph. From the calibration graph find out the ppm of nitrite.

**Procedure:**

Measure out 50 ml of filtrate in the conical flask. Add 1 ml of sulphanilamide solution to each sample. After 2 minutes, but not later than, 8 minutes add 1 ml of N.N.E.D. solution to each and mix immediately. Measure the absorbance at 545 nm. Carry out the procedure with standard nitrite solution also.

**Calculation**:

$NO_2$ = ppm x 150 / 15

***8. AVAILABLE PHOSPHORUS***

***(Olsen's method)***

***(0.5 M sodium bicarbonate extraction*)**

**Principle:**

All soils contain insoluble phosphates mainly di- and tri-calcium phosphates in neutral and alkaline soils and aluminium and ferric phosphates in acid soils. Phosphate ions are present in small concentration in soil solution according to relative amounts of calcium, aluminium and ferric ions. If the concentrations of metallic ions are reduced, concentration of phosphate ions increases in order to maintain various soluble products at their constant values.

An alkaline (pH 8.5) bicarbonate solution can repress the concentration of Ca ions by precipitation as $CaCO_3$ and Al and ferric ions by precipitation as hydroxides. Thus phosphate ion concentrations are increased and available phosphate can be extracted from soil by shaking with alkaline sodium carbonate and filtering. Activated carbon(phosphate free) must be used with most soils to absorb soluble organic matter and it is necessary to allow time for $CO_2$ bubbles to escape.

**Reagents:**

1. Extracting solution: 0.5 *M* sodium bicarbonate (pH 8.5).

   Dissolve 420 g sodium bicarbonate to 10 litres, incorporating about 45 ml 5*N* sodium hydroxide to adjust the pH to 8.5 + or – 0.1.

2. Activated carbon, purified:

   Test the carbon for phosphorus by shaking with extractant, filtering and developing molybdenum blue. If measurable amount of phosphorus is obtained, shake the main stock of carbon with extracting solution, filter and wash the carbon well with water, dry in an oven and pulverize to powder. Retest to establish the absence of phosphorus.

3. Stannous chloride (approx 0.5 *M*) (Stock solution):

   (a) Dissolve 10 g stannous chloride in 25 ml Conc. HCl.

   (b) Diluted Solution – Add 1 ml conc. stannous chloride to 66 ml water.

4. Ammonium molybdate – HCl solution: Dissolve 15 g of ammonim molybdate in 400 ml warm water and filter , add 400 ml of 10 *N* HCl slowly with mixing and make it to 1 litre.

**Procedure:**

Air dry soil should be ground to pass through a 0.5 mm sieve. A 2.5 g soil sample is suspended in 50 ml of $NaHCO_3$ solution of pH 8.5 along with 1 teaspoon of carbon black. Fine suspension is shaken for a period of 30 minutes. The solution is filtered through a Whatman No.40 or other suitable filter paper. A 5 ml aliquot of clear filtrate is pipetted in to 25 ml vol. flask. A volume of 5ml acid molybdate is added and the flask is allowed to stand for the generation of $CO_2$. After that add 10 ml distilled water, then 1 ml stannous chloride (working solution), by immediate shaking and make up the volume to 25 ml and mix thoroughly. Prepare a blank as above and read the intensity of colour developed, at 660 nm, after 10 minutes and within 20 minutes.

**Preparation of standard curve:**

Dissolve 0.2195 g $KH_2PO_4$ in 1 litre $NaHCO_3$ solution. This stock solution contains 50 µg P/ml. Pipette out different quantities of solution from the standard in 25 ml vol. flask, add 5 ml molybdate reagent, add 1 ml diluted stannous chloride. Read the intensity of colour developed after 10 min (660 nm), within 20 minutes.

**Calculation:**

Plot the absorbance values obtained with standard phosphorus solutions against the amount of phosphorus present. From the graph record the number of micrograms of phosphorus corresponding to the absorbance values given by test solution.

ppm P in soil = ppm P in solution $\times$ 25/5 $\times$ 50/2.5 .

### *9. AVAILABLE POTASSIUM*

**Principle:**

For most soils the potassium removed is largely that associated with the clay and humus complex as exchangeable ions but in some saline extracts there may be a fair amount of water-soluble potassium. In the assessment of availability, the exchangeable and water-soluble potassium ions are not differentiated, the sum of the two being measured in the soil extract, usually by flame photometry.

It is accurate enough to shake soil with ammonium acetate solution (1:20 ratio) a procedure that removes 90-95% exchangeable potassium and all water-soluble potassium.

**Reagents:**

1. Extracting solution- ammonium acetate, 1*N* (pH 7.0): Dissolve 77 g of ammonium acetate in 1 litre of distilled water.
2. Standard Potassium-1000 ppm: Dissolve 1.907 g dry potassium chloride in 1 litre distilled water.

**Procedure:**

Transfer a weight of air-dried soil containing 5 g of oven dried soil to 250 ml flask and add 100 ml ammonium acetate. Shake for 30 min. and filter. Measure the concentration of extracts by flame photometry, calibrating photometer with standards containing 0, 5, 10, 15 and 20 ppm K in 1*N* ammonium acetate.

**Calculation:**

From graph, let the concentration of soil extract be ‘A’ ppm K.

Then concentration of potassium in oven dry soil = A x 100/5 ppm

# Instruments for Siltation and Sedimentation Analysis

**Bindu Sulochanan**

### Sedimentation and Siltation

Land clearing and grading have adverse effects on lagoon, mangrove and other estuarine coastal ecosystems due to sediment transportation. Experiments have shown that the erosive power of water flowing with a velocity 'V', varies as '$V^2$' while the transporting ability of water increases to a velocity of '$V^6$'. Sediments, which move as bed load at one section may be in suspension at another section.

As the silt originates from the watershed, the characteristics of the catchment area such as it's aerial extent, soil types, land slopes, vegetal cover and climatic conditions like temperature and intensity of rainfall have great significance in the sediment production in the form of sheet erosion, gully erosion and stream channel erosion.

### Instruments for analysis

1. Automatic sediment analyzer

This instrument estimates the percentage content of grain sizes in a given sample (20 g) automatically.

Principle of operation: Settling time of particles in water is related to their sizes as given by Stoke's law

$mg = 6\pi a\eta v$ where
m- mass of the particle,
g-acceleration due to gravity
a-area of cross section of particle
$\eta$-viscosity of water
v-velocity of the particle

If the settling time is known, the grain size can be estimated from known relationship between settling time and grain size. From a calibrated graph, percentage grain sizes are obtained easily.

### Methodology:

The instrument consists of settling tube filled with water and attached with a settling pan at it's bottom for collecting the sediments. The sample is dropped gently at the top of the column and the particles travel at different speeds depending on their sizes. The weight of materials in water settled in the pan is sensed electronically and indicated in the meter as weight in water. The sediments settle at different times and correspondingly the weight is indicated proportionally. The reading can be noted down against time. Alternatively, a paper chart recorder is used to record the readings and prepare a graph automatically with weight of materials in Y-axis and settling time in X-axis. The graph is characteristic of the sediments giving percentage content of the grain sizes contained.

### Remote silt meter

The Instrument indicates the quantity of suspended silt at different depths of water body. The meter consists of an under water probe and an electronic meter, connected by long cable.

### Principle of operation:

The under water probe is designed for operation in saline as well as fresh water. It senses the suspended silt in relation to density of water. The sensor consists of a submerged float, which undergoes weight loss proportional to density of water as per Archimedes principle. The change in weight loss is converted to inductive pulses and conveyed instantaneously to the meter.

### Operation and data display:

The sensor is immersed in still water from the survey boat/bridges/structures etc. with the sensor attached to long sensor cable.

### Data display:

### Fresh water

1) Data is displayed in digital LCD meters as suspended silt of 0-100gms/l.

2) The meter displays water density in the range of 1-1.1 g/l.

**Saline water.**

The meter makes digital indication of water density in the range of 1-1.2 g/ cc from which silt is estimated.

The recent developments in electronic instrumentation has shown that it is possible to make systematic studies on the influence of siltation, erosion and sediment transportation to mangrove ecosystems. This can reveal significant indications leading to restoration and conservation of the mangrove ecosystems.

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# Craft & Gear in Mangroves - Responsible Fishing

George J. P., M. Srinath, C. Ramachandran, and S. Dam Roy

How to reconcile livelihood concerns of the marginalized people who inhabit the mangrove areas with that of resource conservation. It is indeed the Achilles' heel of any mangrove management programme especially when designed in the context of a paradigm of Responsible fisheries as being advocated the world over.

The FAO code of conduct for responsible fisheries is a landmark document ever produced in the history of world fisheries management. It is a consensus declaration signed by more than 180 member countries of the United Nations. This voluntary instrument was adopted by FAO in 1995. It covers a wide range of fisheries –related activities, including fisheries management, fishing operations, post-harvest practices, trade and fisheries research. The code includes many provisions that support a shift to ecologically responsible fishing. It calls on Governments to apply the precautionary approach, stating that the absence of scientific certainty should not be a reason for failing to take action (FAO code article 6.5).

According to Article 6.8 of the code "all critical fisheries habitats in marine and fresh water ecosystems, such as mangroves, wetlands, reefs, lagoons, nursery and spawning areas should be protected and rehabilitated as far as possible". Particular effort should be made to protect such habitats from destruction, degradation, pollution and other significant impacts resulting from human activities that threaten the health and viability of the fishery resources. At the same time the code also provides that "States should protect the rights of fishers and fish workers, particularly those engaged in subsistence, small-scale and artisanal fisheries, to their livelihood, as well as preferential access to traditional fishing grounds "where appropriate" (Article 6.18).

Obviously it is difficult to resolve this contradiction through legislative measures or enforcement of rules. What is required is facilitating voluntary affirmative action by the stakeholders either to avoid or minimize the use of destructive fishing methods in these critical habitats. A possible stepping stone in this direction would be to make the stakeholders aware about the harmful effects, current as well as what is likely to happen in future, of their fishing activities. In this context a brief discription of the different types of fishing gears prevalent in mangrove areas of the country is given below. In addition suggestions to mitigate and minimize the harmful impacts while operating these gears have also been proposed.

### 1.Cast net

This is a very common gear operated in shallow confined water areas. The operator requires skill to

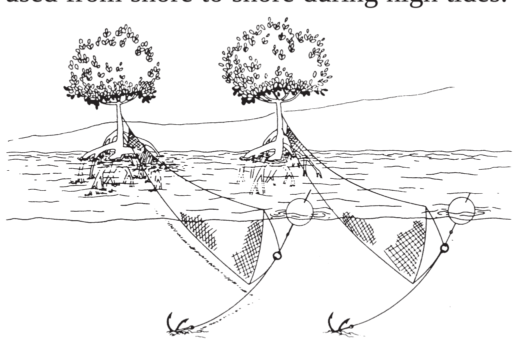
Fishing by cast net - a common pratice mostly in the lentic water bodies handle in casting the net. Depending on the area, nature of underwater terrain and depth of operation, cast nets of varying sizes and mesh are being used in mangrove areas. The total length of the net varies from 2.5 m to 4.5m when fully cast.

**2. Seine nets**

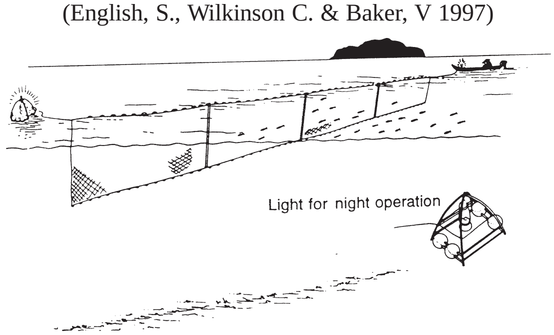
These are encircling nets used mostly in shallow areas. Sometimes fishermen drag and encircle the particular stretch of water body while one end of the net is pulled from the shore. Only organisms of relatively small sizes get caught in these nets and allowed larger ones escape.

**3. Gill nets**

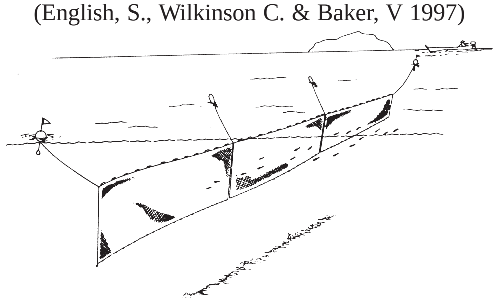
Gillnets are usually used in 2 to 3.5 m deep waters. It has a length of 20 to 40 m and an approximate mesh size of 10 to 60 mm. In some areas, especially creeks, it is used from shore to shore during high tides.



Gill net (passive gear) set out from the bank
(English, S., Wilkinson C. & Baker, V 1997)




Gill net (passive gear) set on the surface. Nets may be anchered or allowed to drift
(English, S., Wilkinson C. & Baker, V 1997)



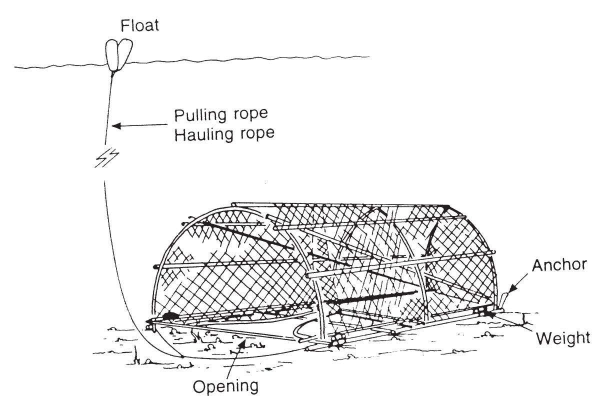
Gill net (passive gear) set in mid water. Nets may be anchored or allowed to drift.
(English, S., Wilkinson C. & Baker, V 1997)

**4. Purse seines**

Purse seines are not common in mangroves. However fishermen resort to this gear during occasions like off-season or when fishing is banned in the sea. The mesh size varies from 2 to 3.5 cm. Purse seines are very rarely employed in mangrove areas in Kerala.

**5. Traps**

**a. Fixed traps**: Fixed traps are very commonly used in mangroves. Long stretches of mangrove areas are seen covered with nets fixed from bottom to surface usually a few feet above the water level using poles that keep the net stretched across shores. The net remains partly submerged during high tide. There is an opening in the centre of the stretched net where the trap is fixed. As the tide recedes water level decreases and the mangrove areas emerge, various aquatic organisms get trapped since there is only one exit from the net. Fishes are scooped out of the traps. This type of fishing is common in mangroves of Northern Kerala.




Fish trap (passive gear)
(English, S., Wilkinson C. & Baker, V 1997)

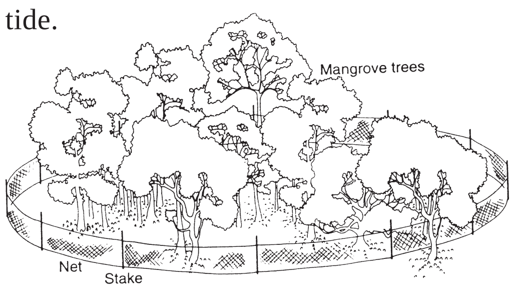
Fish trap in the mangrove

**b. Basket traps**: Mostly women engage in this type of fishing and they use baskets made of bamboo splits. It is more or less oval in shape with three sides elevated while the one side is open. The scooping is done by the open side. Twigs or small branches of mangrove plants are kept inside the basket to attract the fishes. Mostly very small size prawns or juveniles of prawns are trapped by this method.

Basket trap

### 6. Encircling

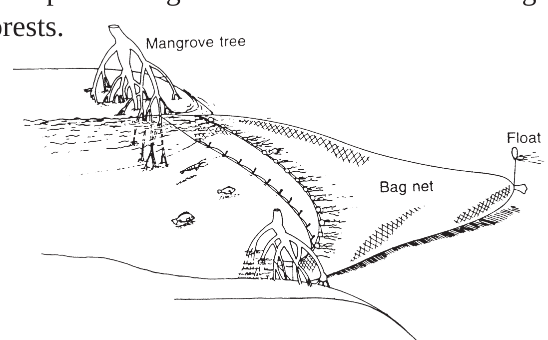
600 m circumference, mesh size 10 to 20mm, expensive, labour intensive, can be operated only in small isolated patches of mangroves. The net is fixed on high tied and fishes are collected during low tide.



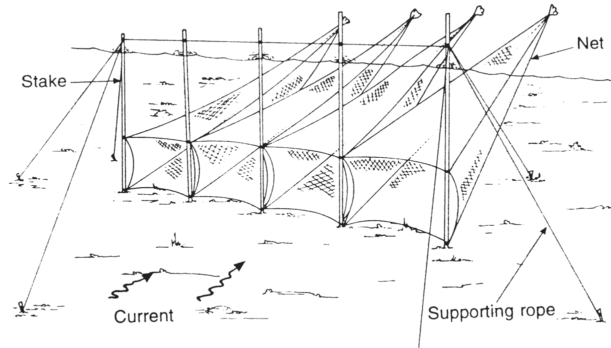

Encircling net (passive gear)
(English, S., Wilkinson C. & Baker, V 1997)

### 7. Bag nets

Operation depends on well defined catchment areas. Chances of escape of fish more from forest floor. Usually mesh size 1.4 cm for fish and 3 mm for shrimp. The bag net set on frinches of mangrove forests.




Bag net (passive gear)
(English, S., Wilkinson C. & Baker, V 1997)




Bag net (passive gear) commercial gear set in main stream.
Usual catch comprises migratory species
(English, S., Wilkinson C. & Baker, V 1997)

### 8. Hand picking

Hand picking of prawns is done by women . The quantity varies from 0.75 kg to 2.25 kg /head for a period of 2-3 hours of labour. They sell it at an average rate of Rs 40-60/kg depending on size, species and quality

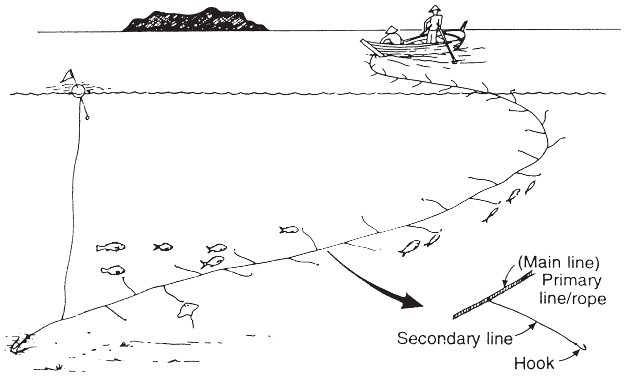
### 9. Seed collection

Collecting the seeds /larvae for aquaculture purposes by drag net and fixed net operation is a common practice in the mangroves of the country. Larvae of *P. monodon* (mostly in Sunderbans West Bengal) and *P.indicus* (mostly in Kerala) fetch attractive prices to the collectors. Fry and fingerlings of *Mugil spp*, *Etroplus* and *Chanos* are also collected from Kerala mangroves.

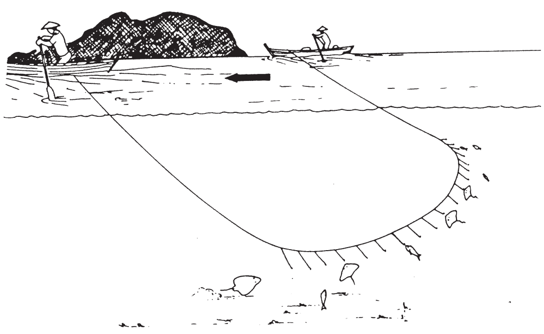
The shallow areas of mangroves are encircled by large plankton nets of mesh size 0.33 mm to collect the larvae, which are stocked in "happas" kept in near shore areas. Later they are scooped by very small hand nets and transported in plastic containers. In Sunderbans fixed nets and individually operated framed dragnets are used to collect *P. monodon*. After dragging a particular stretch the cod end is opened and *P. monodon* is segregated from the collected organisms periodically. The position of the fixed nets are changed depending on the tidal amplitude.

### 10. Long line

In this operation hooks are attached to a long rope which is laid out from non-mechanized wooden crafts. The line is withdrawn at a pre-determined time to collect the catch. Mostly carnivorous species are caught by this method.




Long line (passive gear) set with baits
(English, S., Wilkinson C. & Baker, V 1997)



Long line (passive gear) without baits
(English, S., Wilkinson C. & Baker, V 1997)

### 9. Pole and line

This is a very commonly used fishing method in mangrove areas especially for self-consumption. Sometimes this is done using only hooks attached to nylon strings without using poles and is a time consuming operation.

### Suggestions for Responsible mangrove fishing

1. Use nets with mesh size that allows the escape of juveniles. Nets with very small mesh size should not be used. However it is suggested that location specific mesh size regulations exclusive for mangroves need to be formulated.
2. Use of gears with selectivity is to be encouraged.
3. Collection of seeds /larvae should be based on proper stock assessment and should be undertaken as a monitored seasonal activity. The mangrove fishing community should be trained to do it in an ecologically sound manner.
4. The community should be made aware through concerted extension interventions about the destruction being unleashed by the use of certain gears like fixed traps to the total fishery stock both in inland and marine sector.
5. Locally adaptable fisheries based alternative employment opportunities should be provided / generated to them by the respective Governments. This can include small-scale hatcheries, eco-friendly aquaculture and integrated fish farming.
6. The eco-tourism potential of mangrove regions can be tapped through imaginative planning and participatory implementation of co-management programmes.

   With well-planned efforts the marginalized people / mangrove community staying in these wetland regions can be transformed into responsible custodians and rational beneficiaries of these ecologically sensitive, but invaluable biosphere areas. What is needed is a separate policy for the ecologically rational utilization of mangroves in each maritime state. Mangrove ecosystem management, conservation and security should be closely linked with the lively-hood security of mangrove community.

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# Economic Importance of Mangroves, Afforestation and Reclamation

R. Sathiadhas and George J. P., P. K. Jayasurya and Ansy Mathew

Reclamation/restoration of degraded mangroves by participatory afforestation will give life to an unique environment and form a part of national wealth. Afforestation with a single species of plant suitable for the location is the beginning. Later, mangrove associates and other bio-invasive plants will proliferate and ultimately culminate with the existence of a true mangrove eco-system provided human interventions are restricted. A positive aspect in the cost-benefit analysis of mangrove afforestation programmes is that it does not require any additional cost once the seedlings are properly planted as nature will take care of its further growth. Systematic plantation of mangroves in an area of one hectare costs about Rs.1.08 lakh with the break even cost of Rs.28.85 per tree (Table 1) generating multiple direct and indirect benefits.

**Table 1. Indicative Cost of mangrove afforestation programmes (Rs./ha) (3750 Nos. of plants per hectare)**

| Sl. No | Item | Expenditure (Rs.) |
|---|---|---|
| 1 | Land preparation and planting charges | 60,000 |
| 2 | Seed cost (Rs.10 per one) | 37,500 |
| 3 | **Material cost** | |
| | a) Sand | 600 |
| | b) Clay | 600 |
| | c) Others | 2,000 |
| 4 | Miscell. Expenditure | 7,500 |
| 5 | Total cost | 1,08,200 |
| 6 | Break even cost (Per tree) | 28.85 |

## Direct benefits

Among the direct benefits firewood is the principal component. Nearly 65% of the population is coastal residents. A majority of them are dependent on mangroves for fuel for cooking and timber for shelter construction for self and livestock etc. Therefore, by investing Rs.28.85/plant for planting, approximately five-fold return can be expected within 10 years with regeneration possibilities. As such, though restored artificially the renewed mangroves in course of time provide native population with seemingly endless variety of derived products such as thatching materials, charcoal, medicinal plants, that may grow later in the reclaimed area and animal fodders. In addition the restored mangroves also pave the way for the supply of food materials such as bird's eggs, honey and edible fruits from forest areas and from shore zone; aquatic organisms, such as finfish and shellfish etc. Above to all these mangrove areas are nurseries of numerous marine and brackishwater species and their juveniles grow in the ecosystem. Therefore it contributes substantially towards the capture fisheries resources by way of natural recruitment. Mangrove ecosystems are very favourable environment for a number of economically important species on which the artisanal fishery thrives in the coastal areas. It is indeed fond homes for Brackishwater species such as *Etroplus, Mugil, Lates, Sillago, Chanos, Macrobrachium, Seylla* etc. on which artisanal fishermen earn their livelihood.

Mangrove ecosystem provides many indirect benefits to the native population. Being a common property resource grown in no mans land, there is lack of any management regime or strict accountability on productivity and profitability especially the social benefit it generates to the stakeholders.

## Indirect benefits

Mangroves serve as a natural barrier against the intrusion of the sea by dissipating the wave action and preventing soil erosion. It also helps in the productivity of coastal waters by trapping the nutrients drained off from the uplands which otherwise would have found their way into the deep sea. The high productivity resulting from mangrove litter fall supports a host of detritus feeding animals, which are directly or indirectly related with fish and fisheries. Mangrove is a rich source of antibiotic enzymes and other metabolites of commercial value. This also helps to degrade and assimilate pollutants, pesticides and other chemicals, thus making the aquatic environment safe for other marine life.

Mangroves play a significant role in coastal stabilization promoting land accretion and fixation of mud banks besides helps in dissipating winds, tidal and wave energy etc. It acts as a bioshield which can to a certain extent reduce the impact of gaint waves of Tsunami. The green belt is more ecofriendly than stone walls. Tanin liberated by the mangrove vegetation hardens egg case of fin and shell fishes and ensure better survival for hatchlings. The wax from mangrove leaves and hymenopteran's hives controls predatory aquatic insects. Mangroves are rich in yeast concentration and their enzymatic activities breakdown the cellulose and the hemicellulose from the mangrove litters and pectin from shells of dead crustaceans respectively making carbohydrates, protein etc. readily available to the juveniles of finfish, shellfish and crustaceans which feed on detritus. Mangroves also purify the aquatic systems from hydrocarbon pollution. In general mangroves indeed enriches the coastal productivity. Therefore, this unique fragile wetland ecosystem must be conserved and managed by restoration/reclamation/rehabilitation through afforestation programmes.

Afforestation and reclamation of mangroves is a national necessity which can be done only by Government or public agencies as it generates more social benefit to the society rather than private profitability. Like the development of social forestry programmes, the potential spots of our entire coastal belt should come under the afforestation programmes sponsored by various agencies as there is no better opportunities and alternatives than planting mangroves in these areas for development. Considering the enormous potential demand for the seedlings for massive afforestation programmes, the indicative economics of a small scale mangrove nursery is worked out and given in Table 2.

**Table 2. Economics of small scale mangrove nursery (25000 seedlings/Annum)**

| Sl. No | Items | Quantity | Rate | Cost (Rs.) |
|---|---|---|---|---|
| 1 | Construction and protection of bunds using sand filled gunny bags and mud | - | - | 33,000 |
| 2. | Material cost (Polythene bag) | 100 kg | Rs. 70 | 7,000 |
| 3. | **Labour charges** | | | |
| | a) Collection and transportation of saline mud flaps | 30 labour days | Rs.150 | 4,500 |
| | b) Mixing ingredients and filling the polythene bags | 100 labour days | Rs.150 | 15,000 |
| | c) Transplanting (10,000 Nos.) | 60 labour days | Rs.150 | 9,000 |
| | d) Shifting of polythene bags two times (75 labour days in one time) | 150 labour days | Rs.150 | 22,500 |
| **4.** | **Seedlings cost** | | | |
| | a) Cost of wild seedling of *Rhizophora, Kandelia* sp. | 15,000 Nos. | Rs.2 | 30,000 |
| | b) Cost of *Brugiera, Avicennia, Sonneratia Aegiceras* etc. | 10,000 Nos. | Rs. 2 | 20,000 |
| 5. | Watch and ward | 300 days | Rs. 100 | 30,000 |
| 6. | Boat hiring charges | | - | 5,000 |
| 7. | Miscellaneous expenses | | - | 8,000 |
| 8. | Total cost | - | - | 1,84,000 |
| 9. | Break even cost (per seedling) | - | - | 7.36 |
| 10. | Gross revenue @ Rs. 10 per seedling | - | - | 2,50,000 |
| 11. | Net profit | - | - | 66,000 |

A small scale nursery with an annual production capacity of 25,000 seeds can generate full time

*Sorting out of different trash fishes after catch at Particiaptory Rural Apprisal Technique*

employment for two persons. The break even cost of a seedling works out at Rs.7.36/-, which can be easily sold at a price of Rs.10/-. The gross income generated will be about Rs.2.5 lakh with the net profit of Rs.66,000/- in this venture. However the annual target of region-wise mangrove plantation should be fixed by Government and the requirements of seedlings should be announced in advance. This will enable even unemployed youth to establish mangrove nurseries to cater the increase in demand of quality seedlings. The environmental degradation of the coastal regions can be controlled to a greater extent by developing mangrove forests which will further enhance the livelihood options of fisherflok.

# MANGROVES - SEA - LAND - INTERPHASE - INTER TIDAL - HABITAT : IN THE NATURAL PRODUCTION SYSTEM

*ACANTHUS* BELT PREVENTS SOIL EROSION AND PROVIDE REFUGE FOR THE JUVENILES FROM PREDATION

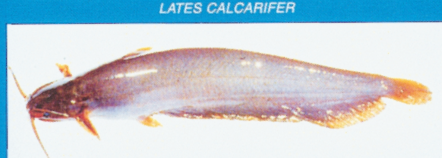
NATURAL NURSERY FOR FISH IN THE MANGROVE

FRESH WATER EEL(*ANGUILLA SPP.)*

*LATES CALCARIFER*

GREEN MUSSEL(*PERNA VIRIDIS*)

OYSTER(*CRASSOSTEA MADRASENSIS*)



FRESH WATER CAT FISH(*SILURUS WYNAADENSIS*)

FRESH WATER CAT FISH(*MYSTUS GULIO*)

*ETROPLUS MACULATUS*

*HYPORHAMPHUS LIMBATUS*

# Methodology for Assessing Status of Fish Stock in Mangroves

**M. K. Patra, S.K. Acharjee and S.K.Chakraborty**

In the world more than 28,500 finfishes have been recorded so far and among these 2200 species have been reported from India (Anon, 1998). Fish constitute chief source of protein and people living in the catchment areas of different aquatic systems depends on fishes for their livelihoods. There the indigenous traditional knowledge (ITK) brought down has turned them into a repository of self experts in fishery sectors in due course of time. Nevertheless, new methodology has been devised utilising the perception of the fisher flocks in order to determine the conservation status of fish stocks of a particular area.

**Methods :**

The earlier method of grouping of fishes into different categories viz. Threatened, Extinct , Endangered, Vulnarable and Rare have been lead to different criticisms and thrown into a stressed situation for their subjective nature and abstractive dimension. The IUCN Council adopted the latest version (IUCN, 2001). (Red List Categories and Criteria. Version 3.1) As a result of recommendations of IUCN (1994) and Species Survival Commission (SSC) (IUCN, 1998) followed by a final meeting of the Criteria Review Working Group in 2000, nine categories of species have been identified. They are Extinct (EX), Extinct in the Wild (EW), Critically Endangered (CR), Endangered (EN), Vulnerable (VU), Near Threatened (NT), Least Concern (LC), Data Deficient (DD) and Not Evaluated (NE). Among these Critically Endangered (CR), Endangered (EN) and Vulnerable (VU) species belong to 'threatened' category and all the nine categories as per IUCN Version 3.1 have been defined as follows :-

**EXTINCT (EX):** A taxon is Extinct when there is no reasonable doubt that the last individual has died. A taxon is presumed Extinct when exhaustive surveys in known and or expected habitats, at appropriate times (diurnal, seasonal, annual), throughout its historic range have failed to record an individual. Surveys should be completed to within a time appropriate to the taxon's life form.

**EXTINCT IN THE WILD (EW):** A taxon is Extinct in the Wild when it is known only to survive in cultivation/culture in captivity or as a naturalized population (or populations) well outside the past range.

**CRITICALLY ENDANGERED (CR):** A taxon is Critically Endangered when the best available evidence indicates that it meets any of the criteria (IUCN, 2001) for Critically Endangered category and it is therefore considered to be faceing an extremely high risk of extinction in the wild.

**ENDANGERED (EN):** A taxon is endangered when the best available evidence indicates that it meets any one of the criteria for Endangered category (IUCN, 2001) and it is therefore considered to be facing a very high risk of extinction in the wild.

**VULNERABLE (VU):** A taxon is Vulnerable when the best available evidence indicates that it meets any one of the criteria for Vulnerable category (IUCN, 2001) and it is therefore considered to be facing a high risk of extinction in the wild.

**NEAR THREATENED (NT):** A taxon is 'Near Threatened' when it has been evaluated against the criteria but does not qualify for Critically Endangered, Endangered or Vulnerable categories now, but is close to qualifying for or is likely to qualify for a threatened category in the near future.

**LEAST CONCERN (LC):** A taxon is 'Least Concern' when it has been evaluated against the criteria and does not qualify for Critically Endangered, Endangered or Vulnerable or Near Threatened. Widespread and Abundant taxa are included in this category.

**DATA DEFICIENT (DD):** A taxon is 'Data Deficient' when there is inadequate information to make a direct or indirect assessment of its risk of extinction based on its distribution and/or population status. A taxon in this category may be well studied and its biology is well known but appropriate data on abundance and / or distribution are lacking. Data Deficient is therefore not a category of threat. It is important to make positive use of whatever data are available. In many cases great care should be exercised in choosing between DD and a threatened status. If the range of a taxon is suspected to be relatively circumscribed and a considerable period of time has elapsed since the last record of the taxon, threatened status may well be justified.

**NOT EVALUATED (NE):** A taxon is 'Not Evaluated' when it has not yet been evaluated against the criteria.

### PARTICIPATORY RURAL APPRAISAL (PRA) METHOD (a case study)

It is a participatory and objective methodology of assigning threatended categories and deriving recommendations for conservation through interactive group dynamics from a number of stakeholders. Selected PRA methods were carefully designed and applied to extract quality primary information relating to the conservation of fishes. The techniques like-Trend Analysis and Matrix and Rank Based Quotient (RBQ) were used. Trend Analysis was carried out to analyse the nature of declining pattern of the target fish population over decades considering the experience profile above 40 years of 50 stakeholders. Fish Magnitude Value (FMV) was calculated through the participatory approach where the decadal availability of a fish species in quantity on exploitation vis-à-vis biomass (Kg) was assessed and that was multiplied by the area of occupancy (Km) [IUCN, 2001]. To avoid the biases in the perceptual assessment, the total score value of the group was divided by the number of stakeholders to have an interpolated mean value. The formula followed was:

$$\text{Mean Fish Magnitude Value (FMV)} = \frac{\text{Biomass x Area of occupancy}}{\text{Number of responding stakeholders.}}$$

The entire process of coining FMV and monthly market landing of the fishes were carried out through the techniques of Participatory Group Dynamics (Mukherjee, 1995) and in conforming with the IUCN guidelines. In the present context the categorisation of fishes has been done considering the decline on FMV and mean decline on market landing of fishes as follows: Critically Endangered (CR) decline on FMV > 80 and mean decline on market landing >60; for Endangered (EN) decline on FMV > 75-80 and mean decline on market landing > 40-60; for Vulnerable (VU) decline on FMV >50-75 and mean decline on market landing > 30-40; for Near Threatened (NT) category, decline on FMV 40-50 and mean decline on market landing 15-30 and for Least Concern (LC) category, decline on FMV and the mean decline on market landing had been < 40 and < 15 respectively. Matrix Ranking was used to isolate and rerank the perceived causes and their relative values in relation to the depletion of target fish population. 20 stakeholders, having experience profile above 40 years, were considered. Rank Based Quotient (RBQ) was calculated to rerank the identified causes in relation to dwindling of fish population (Patra *et al.*, 2003). The formula followed was :

$$RBQ = \frac{\Sigma^{n} fi\ (n+1 - i) \times 100}{Nn}$$

where N = total No. of stakeholders
n = Number of ranks
i = Rank position
and fi = frequency of 'i'.

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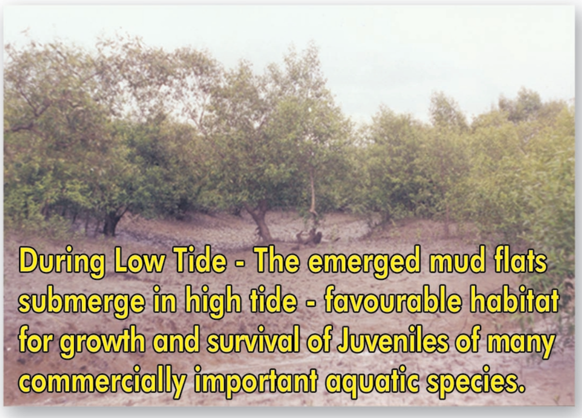
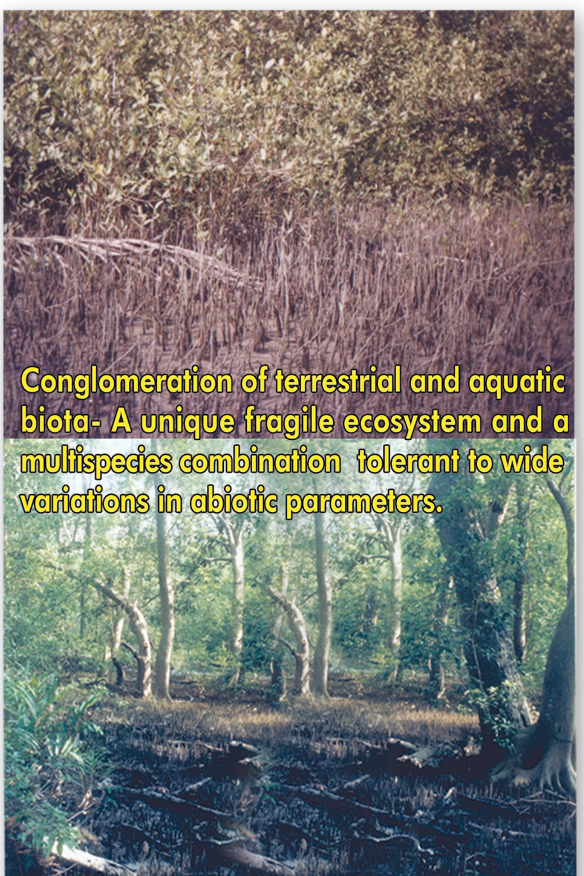
## MANGROVES NATURAL



During Low Tide - The emerged mud flats submerge in high tide - favourable habitat for growth and survival of Juveniles of many commercially important aquatic species.



Conglomeration of terrestrial and aquatic biota- A unique fragile ecosystem and a multispecies combination tolerant to wide variations in abiotic parameters.

## MANGROVES RESTORATION & CONSERVATION

Participatory Afforestation for reclamation of Mangroves.

Natural Propogation of Mangrove Plants- less human intervention.

*Rhizophora mucronata* - Planted for Restoration of destructed mangroves.